NASA

National Aeronautics and
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December 4, 1996

NRA-96-HEDS-03

RESEARCH ANNOUNCEMENT

Fundamental Physics in Microgravity: Research and Flight Experiment Opportunities

Letters of Intent Due: January 27, 1997

Proposals Due: .... March 25, 1997

OMB Approval No. 2700-0042

FUNDAMENTAL PHYSICS IN MICROGRAVITY: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

NASA Research Announcement
Soliciting Research Proposals
for the Period Ending
March 25, 1997

NRA-96-HEDS-03
Issued: December 4, 1996

Office of Life and Microgravity Sciences and Applications
Human Exploration and Development of Space (HEDS) Enterprise
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

NASA RESEARCH ANNOUNCEMENT
FUNDAMENTAL PHYSICS IN MICROGRAVITY:
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NASA RESEARCH ANNOUNCEMENT

FUNDAMENTAL PHYSICS IN MICROGRAVITY: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

This NASA Research Announcement (NRA) solicits proposals for flight experiments and for ground-based experimental and theoretical microgravity research in fundamental physics. The fundamental physics discipline represents a broad range of research areas in the sub-disciplines of low temperature and condensed matter physics, laser cooling and atomic physics, and gravitational and relativistic physics.

Investigations selected for flight experiment definition must successfully complete a number of subsequent development steps, including scientific peer review of the flight experiment and programmatic review of the implementation approach, in order to be considered for a flight assignment. NASA does not guarantee that any investigation selected for definition will advance to flight experiment status. Proposals are sought for a number of flight opportunities beginning in 2002. Investigations selected for support as ground-based research under the Microgravity Science and Applications Division (MSAD) Research and Analysis (R&A) Program generally must propose again to a future solicitation in order to be selected for a flight opportunity.

Participation is open to U.S. and non-U.S. investigators and to all categories of organizations: industry, educational institutions, other nonprofit organizations, NASA centers, and other U.S. Government agencies. **Though NASA welcomes proposals from non-U.S. investigators, NASA does not fund Principal Investigators at non-U.S. institutions.** Proposals may be submitted at any time during the period ending March 25, 1997. Proposals will be evaluated by science peer reviews and engineering feasibility reviews. Late proposals will be considered if it is in the best interest of the Government. Selections are planned to be announced by October 1997. Dr. Mark C. Lee at NASA Headquarters will manage the entire peer review process.

Appendices A and B provide technical and program information applicable only to this NRA. Appendix C contains general guidelines for the preparation of proposals solicited by an NRA.

This announcement is not the only invitation to submit a proposal to NASA for access to the reduced-gravity environment and is part of a planned sequence of solicitations inviting proposals in the disciplines of the microgravity program.

NASA Research Announcement Identifier: NRA-96-HEDS-03
Letters of Intent Due: January 27, 1997, Proposals Due: March 25, 1997

This NRA is available electronically and Letters of Intent can be submitted electronically via the Microgravity Science and Applications Division Web Page at:

http://microgravity.msad.hq.nasa.gov/

Alternatively, Letters of Intent may be submitted via e-mail to the following address: loi@hq.nasa.gov
If electronic means are not available, you may mail Letters of Intent to the following address.

Submit Proposals to:

Dr. Mark C. Lee
NASA c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-03)
300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA can not receive deliveries on Saturdays, Sundays or Federal holidays.

Proposal Copies Required:............**15**

Non-U.S. Proposals. Special instructions apply to non-U.S. proposals. In addition to sending the original proposal (and copies) to NASA through Information Dynamics, Inc. as directed above, one (1) additional copy along with the Letter of Endorsement (see page A-18, Section IX) must be forwarded to:

Ms. Ruth Rosario
ref: NRA-96-HEDS-03
Space Flight Division
Code IH
National Aeronautics and Space Administration
Washington, DC 20546-0001
USA

Proposers will receive a postcard confirming receipt of proposal within 10 working days of the due date.

Any question related to the preparation and submission of the proposal should be directed to:

Dr. Mark C. Lee
Microgravity Science and Applications Division
Office of Life and Microgravity Sciences and Applications
NASA Headquarters
(202)358-0816
mark.lee@hq.nasa.gov

Requests for additional technical background information should be directed to:

Dr. Ulf Israelsson
MS 79-3
Space Sciences Flight Experiment Program Office
Jet Propulsion Laboratory
4800 Oak Grove Dr.
Pasadena, CA 91109
Ulf.E.Israelsson@jpl.nasa.gov

Selecting Official: ....Director
Microgravity Science and Applications Division
Office of Life and Microgravity Sciences and Applications
NASA Headquarters

Your interest and cooperation in participating in this effort are appreciated.

Arnauld E. Nicogossian, M.D.
Associate Administrator,
Life and Microgravity Sciences and Applications (Acting)

APPENDIX A
NRA 96-HEDS-03

TECHNICAL DESCRIPTION

FUNDAMENTAL PHYSICS IN MICROGRAVITY: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

I. INTRODUCTION

A. BACKGROUND

The National Aeronautics and Space Administration (NASA) conducts a program of basic and applied research using the reduced-gravity environment to improve the understanding of fundamental physical, chemical, and biological processes. The scope of the program sponsored by the Microgravity Science and Applications Division (MSAD) ranges from applied research into the effects of low gravity on the processing of various materials to basic research that uses low gravity to create test conditions to probe fundamental laws of nature and the behavior of matter. This announcement is part of an ongoing effort to develop research in a specific scientific discipline, Fundamental Physics.

NASA has supported research in Fundamental Physics for over a decade. Initially, the program focused on the critical phenomena and Low Temperature Physics (LTP) area, but has recently expanded to include research in the fields of Laser Cooling and Atomic Physics (LCAP) and Gravitational and Relativistic Physics (GRP). An extensive MSAD funded research program currently supports theoretical and experimental investigations in ground-based laboratories, that, along with theoretical modeling, form the basis for most of our current understanding of the limitations imposed by gravity on determining the fundamental properties of matter. These ground-based studies form the intellectual underpinning of the research to be conducted in space.

MSAD’s ground-based research program is vital in gaining preliminary understanding of phenomena and in defining experiments to be conducted using the extended low-gravity test times available in low-Earth orbit spacecraft. The highly successful Lambda Point Experiment (LPE) flew on a Shuttle mission in October 1992. LPE demonstrated that the lambda transition in helium remains sharp down to the one nanokelvin level and verified, to much greater precision, the Nobel prize-winning renormalization group theory of critical phenomena. Importantly, the LPE also demonstrated the feasibility of performing very complex high resolution experiments in the space environment. The ZENO experiment, flown in March 1994 and again in February 1996, studied fluctuations near the liquid-gas critical point of Xenon using laser light scattering to reduced temperatures within 3×10^{-8} of the critical temperature. MSAD is currently developing several instruments that conduct fundamental physics experiments in critical phenomena and low temperature physics. Two such instruments, scheduled for flight in the late 1990's, make use of the unique properties of the superfluid transition in ^4He to investigate phenomena such as finite size effects and phase transitions under non-equilibrium conditions. A third instrument will measure the viscosity near the liquid-gas critical point in Xenon. MSAD anticipates near-term Shuttle flight opportunities, starting as early as the year 2000, for investigations capable of making use of existing hardware with only minor modifications. A description of the currently existing hardware can be found in Appendix B.

MSAD anticipates providing flight opportunities for new Shuttle research instruments, early Space Station research instruments, and, if funding allows, experiments aboard free flying platforms to support the broad microgravity research needs of the fundamental physics community. MSAD is currently studying the development of modular research instruments that can be configured (or reconfigured) to accommodate multiple experiments and multiple users. This program of instrument development is envisioned as an evolutionary program with the objectives of providing experimental data in response to increasingly sophisticated science requirements, and of permitting the advance of experimental approaches and technologies as needed for scientific investigations throughout the Space Station era.

This announcement, expected to be repeated periodically, is being released as part of a coordinated series of discipline-directed solicitations intended to span the range of subjects included in the MSAD program. Other solicitations planned for periodic release over the next several years include:

Biotechnology
Combustion Science
Fluid Physics
Materials Science

B. ANNOUNCEMENT OBJECTIVES

This NRA's objective is to broaden and enhance the MSAD program of fundamental physics in microgravity, the goals of which are described in Section III, through the solicitation of:

1. Experimental studies requiring the space environment to test clearly posed hypotheses, using existing or slightly modified instruments to increase the understanding of fundamental physics;

2. Experiment concepts which will define and utilize new instruments for space-based experiments in fundamental physics; and

3. Ground-based theoretical and experimental studies which will lead to the definition or enhance the understanding of existing or potential flight experiments in fundamental physics.

Further programmatic objectives of this NRA include objectives broadly emphasized by the civil space program including the advancement of economically significant technologies, technology infusion into the private sector, enhancement of the diversity of participation in the space program, and several objectives of specific importance to MSAD. These latter objectives include the support of investigators in early stages of their careers, with the purpose of developing a community of established researchers for the International Space Station and for other missions in the next 10 to 20 years, and the pursuit of microgravity research that shows promise of contributing to economically significant advances in technology. Another important objective of the microgravity research program is to support and enhance the ability of humans to live and work in space, primarily through development of advanced technology.

In support of the Human Exploration and Development of Space (HEDS) Enterprise goal to "Enrich life on Earth through people living and working in Space," individuals participating in the MSAD Program are encouraged to help foster the development of a scientifically informed and aware public. The MSAD Program represents an opportunity for NASA to enhance and broaden the public's understanding and appreciation of the value of research in the microgravity environment of Space. Therefore, all participants in this NRA are strongly encouraged to promote general scientific literacy and public understanding of the Microgravity environment and Fundamental Physics through formal and/or informal education opportunities. Where appropriate, supported investigators will be required to produce, in collaboration with NASA, a plan for communicating to the public the value and importance of their work.

C. DESCRIPTION OF THE ANNOUNCEMENT

With this NRA, NASA is soliciting proposals to conduct research in microgravity fundamental physics with an emphasis on experimental efforts that are sufficiently mature to justify near-term flight development. The goals of the discipline are described in Section III along with some research areas that have already been identified to be of interest. Proposals describing innovative microgravity fundamental physics research beyond that described herein are also sought.

NASA is currently developing several types of flight instruments for microgravity fundamental physics research, primarily in the areas of critical phenomena and low temperature physics. Brief descriptions of the existing and planned capabilities are given in Appendix B, Sections I and II. NASA anticipates several near-term flight opportunities, starting as early as 2000, for investigations with requirements which can be met by existing apparatus with only minor modifications. Successful proposals for use of the existing apparatus will be funded for advanced definition studies which will produce a detailed Science Requirements Document (SRD). Authorization to proceed into flight development is contingent upon successful peer review of the experiment and SRD by both science, engineering, and management panels. NASA does not guarantee that any experiment selected for definition which plans to use existing hardware will advance to flight experiment status.

NASA also encourages submission of experiment proposals in all areas of microgravity fundamental physics for which none of the existing flight instruments is appropriate. NASA anticipates the development of new apparatus for fundamental physics research experiments for use in 2000 and beyond. The need for development of new apparatus in the areas of Laser Cooling and Atomic Physics and in Gravitational and Relativistic Physics appear especially urgent. Descriptions of possible future apparatus capabilities can be found in Appendix B, Part II. These hardware descriptions are included as examples to allow researchers to consider the type of capabilities that might meet their science requirements. However, researchers should not feel limited by these capabilities.

Selected proposals requiring development of new capabilities will be funded for definition studies to determine the parameters and conditions for a flight experiment and the appropriate flight hardware. The length of the definition phase will be based on the experiment requirements, but will normally range from 6 to 24 months and will culminate in the preparation of a Science Requirements Document (SRD) and the conduct of a Science Concept Review (SCR). Authorization to proceed into flight development is contingent upon successfully passing first the Science Concept Review and later the Requirements Definition Review (RDR), where science, engineering and management panels review the final SRD and the plans for implementing the proposed experiment. NASA does not guarantee that any experiment selected for flight definition which requires new instrument development will advance to flight experiment status. In fact, to ensure that the highest quality experiments are flown in space, MSAD will strive toward selecting, on the average, up to two experiments for flight definition for each experiment that will actually fly. Flight investigations that do not proceed into flight development will normally be asked to submit a proposal for continuation of support at the conclusion of a typical four-year period of funding. Promising proposals which are not mature enough to allow development of a flight concept within two years of definition may be selected for support in the MSAD Research and Analysis (R&A) Program. Investigations selected into the R&A program must generally be proposed again to a future announcement in order to be selected for a flight opportunity.

II. **RELEVANCE TO HUMAN EXPLORATION AND DEVELOPMENT OF SPACE**

The Microgravity Science and Applications Division is organizationally part of the NASA enterprise with a mandate to foster Human Exploration and Development of Space (HEDS). This section is provided as information for proposers to establish the connection between the microgravity fundamental physics program and the HEDS enterprise. The four goals of the HEDS enterprise are:

1. Understand and use nature’s processes in space

2. Explore and settle the solar system
3. Achieve routine space travel
4. Enrich life on Earth via people living and working in space

The fundamental physics of today provides the foundation of tomorrow's technology. This has been true since humans first developed scientific curiosity. The resulting technological advances have led to enhanced living standards for the average member of our society and to innovations needed by the space program. For example, the research on gases at low temperatures, begun by low temperature physicists in the latter half of the 19th Century, is a perfect example of how fundamental physics has contributed to technology and to the well-being of the average "person on the street". This research led to techniques for gas liquefaction which today are applied to such diverse problems as freeze-drying food products, rocket propulsion, operation of superconducting magnets, cryo-surgery, and magneto-encephalography. Particularly, in recent decades we have seen many far-reaching examples of fundamental physics impacting dramatically and positively on how we and our society function. The most well known are the effects of semiconductor physics on communications and computing technology, the relation between fundamental NMR studies in the laboratory and MRI imaging in our hospitals, and the impact of fundamental studies of laser physics on a whole host of technical problems.

The technological foundation built on fundamental physics advances includes the technology necessary for humans to effectively enter, live in, and work in space. In support of the demands of various goals of HEDS Enterprise, the Fundamental Physics program will continue to support world-class science to better understand the role of gravity in nature's processes. These studies will also foster an underlying knowledge base on which new and improved physical processes and systems can be formulated.

Cryogenic fluid management is of critical importance to the exploration of space and to the utilization of resources on remote sites. Basic low-temperature and condensed matter physics studies are needed to contribute to technological advancements in storage, liquefaction, and handling of cryogens, thus making it economically feasible to provide for the bulk scales needed in space travel and utilization. Systems using the data base provided by the Mars and Lunar-gravity simulator can be developed to enable low-cost cryogen handling in non-Earth environments.

The fundamental physics program is at the forefront in the development of such diverse technologies as ultra-sensitive sensors (many based on superconducting technology) and of highly accurate clocks. These technologies will likely find applications in the future human exploration space program as well as in enhancing the lives of people on Earth. Clocks not only provide the standard by which we tell time, but are crucial to the way we communicate and navigate on Earth, in the air, and in space. By developing more accurate clocks, a more precise deep space navigation system can be implemented.

III. MICROGRAVITY FUNDAMENTAL PHYSICS RESEARCH

Not all problems in physics can benefit from the microgravity environment of space. For example, most experimental studies in high-energy physics and many problems in solid-state physics are excluded, because inter-particle or inter-atomic interactions are so strong as to totally mask gravitational forces. Problems in physics where the microgravity environment can be beneficial include those subfields where other (electromagnetic) interactions are weak, where extremely uniform samples free from hydrostatic compression are required, where objects must be freely suspended and their acceleration must be minimized, or where the mechanical disturbances unavoidably present in an Earth-bound laboratory must be eliminated. Experiments in these categories often can benefit either from the dramatically reduced gravity available in space, or from the use of variable gravity as a parameter whose change may lead to the elucidation of otherwise hidden properties and phenomena. The physics of critical points in fluids is prominent among the issues in condensed matter physics which have been investigated so far under microgravity conditions. Microgravity plays an important role in these investigations because the closeness of approach to a critical point in the Earth-bound laboratory is limited not by the skills of the experimentalist, but rather by the uniformity of the sample which is spoiled by hydrostatic pressure variations. A second category of phenomena presently under investigation comes from the field of atomic physics. The aim here is to retain atoms virtually without motion in a cavity for extended time intervals. However, the length of time that the atoms can be held in the cavity is limited by the gravitational acceleration experienced on Earth. This second category also includes the study of freely suspended rotating superfluid-helium drops. A third category of investigations that will benefit from the opportunity to virtually eliminate all mechanical disturbances in space. For example, such disturbances limit proof-mass technique experiments probing fundamental questions in gravitational and relativistic physics, where the positions of objects relative to each other must be maintained and measured with a resolution unobtainable in the gravitationally noisy environment on Earth.

One of the unifying characteristics of physics as a whole is that the field addresses fundamental issues which transcend the boundaries of a particular field of science. It is typical that, at one extreme, the fundamental laws of our universe, such as the law of gravitation, should be the central issue. Clearly these laws are relevant to various extents in many branches of science. At another extreme, in condensed matter physics, those unifying principles are studied which arise from the interaction of (infinitely) many degrees of freedom on vastly different length scales. Examples of this type of study can be found in the research on critical phenomena mentioned above, which addresses fundamental problems of nonlinear physics which pertain equally to fluid, solid-state, chemical, or biological systems.

The majority of fundamental physics experiments in microgravity represent extensions of investigations in Earth-bound laboratories. Most of them, when conducted on Earth, are relatively small projects (sometimes called “table-top experiments”) which are conducted by a single investigator and a small number of students or postdoctoral associates. In these cases, the microgravity experiment represents an opportunity to extend a set of measurements beyond what can be done on Earth, often by several orders of magnitude. This extension can lead either to a more precise confirmation of our previous understanding of a problem, or it can yield fundamentally new insight or discovery. NASA recognizes that the close relationship between ground-based research and research utilizing microgravity makes it particularly important to maintain a vigorous program of (relatively inexpensive) Earth-bound projects, together with an appropriate number of microgravity investigations. The importance of this dual approach to maximizing scientific output is two-fold. First, in most cases only a vigorous ground-based program will identify the experiments which are most worthy of consideration for microgravity. Thus, it is expected that the microgravity experiments are a natural outgrowth of the ground-based program. Second, a microgravity experiment should be performed already on Earth to its maximum potential to determine if a highly complex experiment will be successful when conducted under microgravity conditions.

The following sections describe the research areas covered by this announcement. These research areas have been organized into sections on Low Temperature Physics and Condensed-Matter Physics (LTCMP), Laser Cooling and Atomic Physics (LCAP), and Gravitational and Relativistic Physics (GRP). However, proposals of innovative microgravity fundamental physics research beyond that described below are also sought.

A. LOW TEMPERATURE AND CONDENSED MATTER PHYSICS (LTCMP)

1. Critical Phenomena. The theoretical foundation of critical phenomena is provided by the Renormalization Group (RG) theory. The physics of critical-point systems is extremely diverse, but at the same time, it is unified through the framework of the RG theory. Different phase transitions can be categorized as belonging to different universality classes according to general symmetry properties of the order parameter and the conservation laws of the system. Two important critical points, belonging to two different universality classes, are the superfluid transition in liquid helium and the liquid-gas critical point. Within a given universality class, the critical behavior of various properties is predicted to be the same except for a small number of constant multiplying factors which are system specific, and there are both thermodynamic and transport properties to be studied and understood. A third important system is the tricritical point in ^3He-^4He mixtures.

Tricritical points are very special because, for them, the leading critical behavior is given exactly by mean-field theory. In this case, the RG theory makes exact predictions about corrections to this mean-field behavior. These corrections take the form of fractional powers of logarithms.

In liquid helium, the order parameter is not directly observable, while room temperature gas-liquid critical points display their order parameter quite vividly in the phenomenon labeled “critical opalescence” where light scattering from the density fluctuations turns a normally clear fluid milky as the sample passes through the critical point. Therefore, room temperature critical point experiments concerning the turbidity of fluids near gas-liquid critical points can provide new information about the interactions of the density fluctuations. One of the thermodynamic variables that increases anomalously at a gas-liquid critical point is the compressibility, so, on Earth, gravity forces cause only a small portion of the height of a sample to be at the critical point at a given temperature. Microgravity experiments can measure the turbidity of large regions that are very near the critical point, thus enabling larger fluctuations to be explored so new regions of the parameter space can be investigated.

There are many aspects of the RG theory, and only some of them have been or are being explored by current or planned flight experiments. Therefore, opportunities for contributions to fundamental physics remain in this area.

2. Solid-Fluid Interfaces. One important issue in CMP is the nature of the interface between solids and fluids. The boundary conditions which prevail at this interface have an influence on macroscopic phenomena, including wetting, surface phase transitions, and film formation. The microscopic aspects of the system near the boundary are difficult to study. However, when the fluid is near a critical point, the boundary layer adjacent to the solid surface acquires a macroscopic thickness. If the fluid phase is of limited spatial extent, the boundary will then significantly influence the average macroscopic properties of the system. Thus, a critical fluid system which is confined can be used to study boundary effects. These finite-size effects can take several forms, depending on the nature of the confinement. For instance, the sample might be contained between parallel plates, as is the case for the Confined Helium Experiment (CHeX). On the other hand, quantitatively different results are expected when the fluid is contained in long, narrow cylinders. Again the RG theory is expected to provide a unifying framework for understanding these phenomena. Large-scale computations using Monte Carlo methods with suitable models can also be used to study these effects. In these theoretical studies the boundary conditions and the confining geometry can be varied in a controlled fashion. Interesting issues include not only the influence of the boundaries on thermodynamic properties; of equal interest are transport properties such as heat or mass transport. Very little is known experimentally about transport in confined systems, which should be viewed as a new important area of research to pursue.

Any critical point experiment performed in a finite-sized apparatus must carefully estimate the effects that limiting the size of the fluctuations can have on the measurements. This is especially true at gas-liquid critical points conducted on Earth, where the rapidly increasing compressibility means that the region of the fluid that is critical is limited by the gravity-induced density gradient to a small section of the height, there is little hope for obtaining measurements very close to the critical point that are uncorrupted by this size limit. The inaccessibility of the order parameter at the lambda transition implies that another system, where the size of the fluctuations can actually be measured, could better display the effects of limitations on the size of order parameter fluctuations. As described above, the gas-liquid critical point provides a dramatic display of these fluctuations, and the ZENO flight experiment that flew in March 1994, and again in February 1996, has demonstrated that in microgravity these fluctuations can be studied with scattering of laser light to reduced temperatures within 3×10^{-8} of the critical temperature. That close to T_c the fluctuations have sizes of the order of 10^{-3} cm, so experiments can be devised to measure the effects of confining these gas-liquid systems in one, two, or three dimensions with well-characterized confining materials.

3. The Physics of Thick Fluid Films. The study of fluid films under typical terrestrial conditions is limited to films with a thickness no more than tens of nanometers because thicker ones will “drain." Interesting physics could be learned from the study of thicker films that would be available

in a microgravity environment. Some of the interesting issues to be addressed include the problem of the superfluid transition in liquid helium. Although helium can be studied when confined between two rigid plates of separation d, the film of equal thickness d has the potential to yield information about the difference in boundary conditions at the liquid and solid surfaces. This issue of boundary conditions is of fundamental importance in condensed matter physics. Other issues of interest in thick superfluid helium films is the nature of sound propagation within them. One expects interesting behavior when, as the thickness of a superfluid film increases, one encounters the crossover from "third sound" (a tidal wave) on the film to "second sound" (a temperature wave that propagate in bulk superfluid helium). Almost certainly a number of other fundamental issues will arise as the study of thick films becomes available in the microgravity environment. For example, third sound is dominated by van der Waals forces in thin films but, as the thickness increases, surface tension becomes a more important force, and the crossover in behavior has not been well studied.

As for the discussion on finite size effects above, critical points can also be used to advantage in the study of many properties of thick fluid films, where the detailed behavior is determined by boundary conditions of the free vapor interface and of the solid boundary.

4. Non-equilibrium Systems. There are many non-equilibrium systems on Earth and in space, which are constantly evolving, and yet much of physics is studied by considering the idealized case of equilibrium. The statistical dynamics of many-particle systems in metastable equilibrium or in non-equilibrium is an important field of physics which is far from being well developed and well understood. When non-equilibrium phenomena have been considered, this usually has been done within the framework of linear response theory which applies when departures from equilibrium are small. Indeed, in laboratory systems it is often difficult to achieve sufficiently extreme conditions for linear response theory to break down under well controlled circumstances which permit quantitative study. However, such conditions can be achieved more readily in the vicinity of critical points where typical relaxation times become large. Thus, we can exploit the criticality of a system to explore extreme non-equilibrium conditions where transport becomes a nonlinear phenomenon. The superfluid transition of ^{4}He is a system which is particularly suitable for the study of these phenomena, and the Critical Dynamics in Microgravity Experiment (DYNAMX) is designed to investigate some of its transport properties. However, there are additional aspects which are beyond the scope of DYNAMX which should be pursued. These include the effect of non-equilibrium conditions on thermodynamic properties and on the behavior of confined systems. Studies of non-equilibrium conditions in ^{3}He-^{4}He mixtures may also benefit from a microgravity environment, as well as measurements of viscosity in fluids near gas-liquid critical points constitutes a study of a system out of equilibrium. A planned flight experiment for making such measurements in xenon (T_c = 16.6 C) is the Critical Viscosity Experiment. Many other subjects are available for study in this largely unexplored fundamental subject area of dynamics near critical points.

5. Superfluid Hydrodynamics. A number of highly interesting experiments in superfluid hydrodynamics exists which can be carried out under microgravity conditions. One class addresses the intrinsic nucleation problem for quantized vortices in helium II. Almost all nucleation experiments (apart from microscopic ions) suffer from extrinsic nucleation effects. For example, rotation of a bucket of superfluid always produces an array of quantized vortices which appear at velocities much lower than would be expected for intrinsic nucleation. Very likely residual vortices pinned to the boundaries are responsible. If we study the dynamics of a liquid drop suspended away from any boundaries, and if the temperature is low enough that vapor around the drop is for all practical purposes gone, then there cannot be any way to have pinned vortices and presumably nucleation must be truly intrinsic.

Another type of experiment can be to set a drop into rotation at a temperature below 1 K and look for nucleation of a quantized vortex line. In the absence of any impurity in the drop, there should be no nucleation: The normal fluid, which makes up less than 1% of the fluid at 1 K, should rotate and the superfluid should remain at rest. The vortex nucleation is prevented because there is no way for a residual vortex line to remain pinned in the drop. The rotation of the drop would then be free of vortices and, hence, the superfluid should remain at rest up to angular velocities much higher than could be attained if a spherical container were used.

In yet another experiment, a helium drop could be rotated rapidly to observe the deformation from the spherical shape against the force of surface tension. Much theoretical work exists on the shapes of rotating fluids, and one microgravity experiment has been performed already on the space shuttle using water as the working fluid.

Creation and suspension of drops offers other classes of experiments studying collisions of drops and coalescence. One could even imagine studying the collisions of ^3He and ^4He drops, or a suspension of one or more ^4He drops in liquid ^3He. Experiments with drops of liquid or solid hydrogen could also be done. At low enough temperatures, hydrogen also behaves as a quantum fluid (or solid).

A different set of microgravity experiments with superfluid helium which has been considered is to look for manifestations of long-range quantum coherence in superfluid drops. If low-energy helium atoms are fired at a drop of superfluid, analysis of the atoms emerging from the opposite side should contain information about the condensate.

6. Melting-Freezing and the Growth of Crystals. First-order phase transitions, involving the processes of melting and freezing and of crystal growth, have long been of fundamental interest to physicists. Extensive and detailed studies of a wide range of physical processes associated with first-order transitions have been carried out. Prominent among the issues of interest are the mechanisms involved in the transfer of atoms from liquid to solid and vice-versa, nucleation (initiation) of a new phase within an existing one, and diffusive and ballistic mass transport. In addition, an important aspect of crystal formation involves the critical phenomena that govern the evolution of crystal shapes, that is the so-called roughening transition and associated phenomena. In the presence of gravity, various forms of convective flow have inhibited many of these studies.

Helium offers unique opportunities for these studies for several reasons. The first of these is its quantum nature that offers the opportunity to study properties not accessible in ordinary (classical) solids. The second includes several characteristics which make such studies possible under microgravity conditions. As an example of these characteristics, we note the relatively fast diffusion, and resulting short relaxation times for shape changes, of helium crystals on their approach to equilibrium. This rapid approach to equilibrium is in contrast to classical solids for which these times are often prohibitively long, especially in comparison to time scales accessible to experiments under microgravity conditions.

Studies of the quantum nature of the solidification process of hydrogen may also benefit from a reduced gravity environment.

B. LASER COOLING AND ATOMIC PHYSICS (LCAP)

One of the most dramatic advancements in atomic physics over the last decade has been the demonstration that laser light can be used to cool a dilute atomic sample to within microdegrees or even nanodegrees of absolute zero. At these low temperatures, the mean velocity of the atoms drops from several hundred meters per second to centimeters per second or even smaller, a reduction by four to five orders of magnitude. In this quantum regime, the gravitational energy far exceeds the mean atomic kinetic energy and the effects of gravity dominate atomic motion. For example, the energy gain of a cesium atom as it falls a centimeter in Earth's gravity corresponds to an increase in its temperature of 1500 microkelvin, while a lighter atom such as lithium gains 80 microkelvin per centimeter.

1. Atomic Clocks. Among the most important technological contributions of modern atomic physics is the development of ultra-high precision clocks. These clocks not only provide the standard by which we tell time, but they are crucial to the way we communicate and navigate on Earth, in the air, and in space. Without question, atomic clocks affect almost every aspect of modern life. Two vital concerns in the conception of such ultra-high precision devices are: (1) that the precision is inversely proportional to the observation time (this stems from the uncertainty relation ($\Delta E \Delta t \geq h/2\pi$) and (2) that the first- and second-order Doppler shifts associated with motion

of the atoms can cause broadening of the atomic transition, thereby compromising the measurement accuracy and precision. Laser-cooled atoms have significantly pushed back both of these limitations. Very cold atoms move ***very*** slowly, reducing Doppler shifts, and they remain in a given observation volume for ***very*** long times, thereby reducing line-broadening caused by the uncertainty relation. Indeed, compact cold atom clocks have already been built and have provided a short-term stability which is significantly better than the existing standards. Nevertheless, limits on observation times in these clocks are still set by gravity. Ultimately, the atoms fall out of the experiment under their own weight. Increased observation times are possible in microgravity and can result in further improvements in clock stability by at least one or two orders of magnitude. A long-term accuracy near a part in 10^{17} is expected making these clocks three orders of magnitude better than presently accepted standards, and additional orders of magnitude better than most space ready clocks.

As a starting point, high performance space clocks are an absolute necessity for the human exploration and development of space because of the central role that time measurements play in navigation. High performance space clocks will also result in improved capabilities for terrestrial navigation through improvements in the global positioning system (GPS). High performance space clocks will have an even deeper impact on our understanding of nature. For example, the development of an ensemble of high performance space clocks which operate on different physical processes will allow unique tests of fundamental physics. Relative drifts between the clocks can be used to detect the drift between the coupling constants of different fundamental forces (the strong force, electroweak, etc.) - coupling constants which lie at the very heart of the accepted description of nature.

2. Fundamental Forces and Symmetries. Almost every precise measurement made in science ultimately traces to a time or frequency measurement (thermometry, distance, pulsar period, etc.), and both terrestrial and deep space navigation rely crucially on precision clocks. However, the potential use of ultra-high precision cold-atom clocks in the microgravity program is of deeper significance. At the heart of the atomic clock is a measurement of a carefully chosen energy level splitting within the atom. These splittings are not only nature's own reference “standards" but, at the resolution which can be expected using microgravity clocks, the splittings become measurably sensitive to subtle aspects of fundamental forces and to basic symmetries of nature. Usually, these last classes of questions are the realm of high-energy or “particle" physics. Ultra-high precision atomic measurements, however, can now make important contributions to answering these questions, and the use of microgravity can play a vital role in enhancing this contribution. For example, parity non-conservation experiments in atomic cesium already compete with accelerator based measurements for the determination of the Weinberg angle, a direct measure of the electroweak mixing angle in the Weinberg-Salam model (and a number which determines the ratio of the W to Z boson masses). As with any clock type measurement, one important limitation of these experiments is the observation time. This limitation can be minimized in space experiments.

A related experiment is the search for the permanent Electric-Dipole Moment (EDM) of the electron. The existence of an EDM can be traced directly to time reversal (T) and/or charge-conjugation parity (CP) violating interactions, or, in other words, to the most basic symmetry properties of nature and of the physical laws describing nature. The EDM measurement consists of a ***very precise*** determination of the response of the atomic level splitting to an applied electric field. Essentially, this is a clock-type measurement. Using microgravity, a cold-atom clock can provide at least ***two orders of magnitude of improvement*** in the current EDM measurements. Regardless of the exact outcome of the EDM experiments, the results are essentially ***guaranteed*** to be significant: If this experiment detects no moment, several theories of CP violation competing with CP-violating interactions present in the standard model can be eliminated, such as CP violating interactions in super-symmetry, flavor changing, etc. On the other hand, detection of a moment will demand far-reaching revisions in the foundations of physics.

3. Bose-Einstein Condensation and Quantum Gasses. The physics of laser cooled vapors is closely tied to the physics of quantum fluids and statistical mechanics. Dramatic phase changes such as the condensation of large numbers of atoms into the lowest state of the system, called Bose-Einstein condensation, are being investigated by the laser-cooling community and new

insight into quantum transport phenomena is steadily being gained. As lower and lower temperatures are achieved using evaporative cooling, gravitational limitations have already emerged. For example, the energy bias introduced by the gravitational field may vastly reduce the efficiency of evaporative cooling, the final cooling step used to pass into the Bose condensed phase. Furthermore, the investigation of freely expanding sub-nanokelvin condensates as well as very dilute condensates will become increasingly difficult and, eventually, impossible on Earth's surface due to gravitational effects. Within this component of LCAP, a strong synergy with related work in Low Temperature and Condensed Matter Physics is expected.

4. Atom Optics. Progress in atom optics has given rise to the development of a number of remarkable devices, most notably the atom interferometer. Reaching far beyond the initial goal of demonstrating the interference of matter waves of massive, complex particles, the atom interferometer has been used to realize high performance rotation sensors (gyroscopes) and gravitometers which provide unprecedented performance. As in other LCAP experiments, the elimination of gravity can allow significant improvements in many atom optical experiments. Of additional importance is the application of microgravity atom optics and interferometry to fundamental problems such as improving our knowledge of the gravitational constant G (the least well known of all fundamental constants of nature) as well as to terrestrial applications such as ultra-high performance geodesy. Furthermore, there are significant opportunities for microgravity atom optics experiments to compliment other Fundamental Physics experiments in general relativity and gravitation. For example the comparative testing of the Equivalence Principle for macroscopic (classical) bodies, as investigated by the Satellite Test of the Equivalence Principal (STEP) (see below), and for microscopic (quantum) particles, as investigated using atom interferometer based gravitometers.

5. General Relativity. The clock itself reaches deeply into the foundations of physics. As is apparent in any discussion of relativistic effects, clocks are central in the realm of general relativity and in questions concerning the very nature of gravity itself. Here the motivation for space-based atomic clocks is tied not only to the improved performance expected in a microgravity environment, but is also tied to the fact that these clocks will have access to ***fundamentally different positions in space-time than are available on Earth***. An important example of this latter physics is that revealed in the comparison of an Earth-based clock with a space-based clock. This comparison provides a direct measurement of the gravitational red-shift, the reduction of frequency caused by a change in the clock's gravitational potential. Indeed, improvements of one to two orders of magnitude of the current accuracy of 70 parts per million can be expected using space-based ultra-high precision clocks to measure these shifts. Measurements of the gravitational red-shift also test important aspects of the local position invariance part of Einstein's Equivalence principle (see below) and are tied to the possible spatial variation of the fine-structure constant α, a parameter central to quantum electrodynamics.

It is recognized that a role of the advanced laser technology crucial for microgravity LCAP will be to open the door for a remarkable generation of general relativity experiments which require large spatial separation of experimental components, such as the measurements of the retardation of photons grazing a massive celestial body (for example the sun), or for dramatic improvements in laser based general relativity (GR) experiments such as the Kennedy-Thorndike experiment. A strong synergy of LCAP GR experiments with other GR projects within Microgravity Fundamental Physics is anticipated.

6. Advanced LCAP Development. Without question, pivotal steps in the progress within LCAP have derived from important developments in experimental techniques and in optical technology. The need for the development of enabling technologies is therefore clear and is recognized as a potential support area with LCAP. An equally crucial factor in the development of LCAP related fundamental physics has been the ability of the theoretical community to both predict new directions for experimental investigation and to interpret many decisive experiments. It is expected that theoretical projects can therefore play a decisive and natural role within the LCAP area.

C. GRAVITATIONAL AND RELATIVISTIC PHYSICS

Tests of Einstein's theories of relativity and of other metric and non-metric theories of gravitation serve as a foundation for understanding how matter and space-time itself behave at large length scales and under extreme conditions. The free fall environment of space, the use of low temperature techniques, and the use of high precision frequency standards offer opportunities to perform improved tests of these theories significantly beyond what is possible on the ground.

Einstein's Equivalence Principle (EEP) provides a foundation for all metric theories of gravity. To verify the range of validity of different EEP aspects is crucial to the quest for unifying all fundamental forces of nature. Gravitation, electromagnetism, and the weak and strong interactions in nuclei, are the four known fundamental forces of Nature. The present theory of gravity is intimately connected to the theory of General Relativity. General Relativity is a “classical”, non-quantum theory of curved spacetime and it constitutes an as yet unchallenged description of gravity interactions at macroscopic scales. The other three forces are described by a quantum field theory called the “Standard Model” of particle physics, which accurately describes physics at short distances where quantum effects play a crucial role.

Despite the beauty and profundity of Einstein's theory and the success of the “Standard Model” our present understanding of the fundamental laws of physics has serious shortcomings. At present no realistic theory of quantum gravity exists. The “Standard Model” successfully accounts for all existing non-gravitational particle data. However, just as in the case of General Relativity, it is not a fully satisfactory theory. It suffers from unresolved problems concerning the violation of the CP symmetry between matter and antimatter and the various unexplained mass scales. Purported solutions to these shortcomings typically involve new interactions that could manifest themselves as apparent violations of the EEP. One should note the overlap of the precision measurements of the laser-cooling experiments with Gravitational and Relativistic Physics in mounting challenges to the Standard Model with tests like the search for a finite electric dipole moment in the electron, a test of time reversal symmetry.

It has been experimentally verified that gravity couples to light, or photons, the massless particles that “mediate” the electromagnetic force. In the same manner, gravity should also couple to the other massless particles that mediate the interactions between the many sub-atomic particles. The way in which gravity couples to the total mass-energy of matter is key to understanding the EEP.

The construction of a “Grand Unified Theory” of weak, electromagnetic and strong interactions seems to require, for theoretical as well as experimental reasons, the existence of a supersymmetry between particles of different spins. This framework suggests the existence of new interactions beyond those of the “Standard Model”. In particular, the exchange of new spin-one particles could lead to a new repulsive force between macroscopic bodies, which might be detected through small deviations from the EEP.

The truly outstanding problem remains the construction of a consistent quantum theory of gravity, a necessary ingredient for a complete and unified description of all particle interactions. Superstring theories--in which elementary particles would no longer appear as pointlike--are the spinless partners of the graviton: “dilatons” and axion-like particles. The dilaton, in particular, could remain nearly massless and induce violations of the EEP at a level that may be detectable.

In a microgravity environment, the weak equivalence, local Lorentz invariance, and local position invariance aspects of EEP can be tested independently at high precision. For example, Gravity Probe A verified the expected local position invariance of EEP to 70 parts in a million by measuring the frequency shift between a hydrogen maser in Earth orbit and a hydrogen maser on Earth. High resolution experiments can use ultra-sensitive superconducting test mass techniques to test the weak equivalence principle with many orders of magnitude better precision than previously accomplished. Other aspects of EEP can be tested by using high stability frequency standards in various arrangements.

Direct tests of gravitation theories and of other fundamental theories can also be performed advantageously in a microgravity environment. Superconducting accelerometer test mass techniques and frequency standards techniques can be used to study the Lense-Thirring effect, test the inverse square law of gravitation, and to search for weak coupling forces through axions and through other potential near-massless bosons. Ultra-stable frequency standards can be used to investigate time and spatial variations in the fine structure constant and in the gravitational constant.

Although the physics is closely related, applications of gravitational physics to Astronomy, such as the search for (and use of) gravitational waves, is considered to be under the program responsibility of the Office of Space Science and is not covered by the microgravity fundamental physics discipline.

IV. DEVELOPMENT OF RESEARCH ENABLING TECHNOLOGY

This NRA also solicits technology development activities in areas that will enable new scientific investigations in the microgravity fundamental physics program to be performed. MSAD is planning to select one or two projects in this category. Funding will be at the same level as ground based scientific investigations. Primary importance in the selection process will be the extent to which the proposal will enable the conduct of new and improved scientific investigations in the microgravity fundamental physics area. Secondary importance in the selection process will be placed on the extent to which the proposed technology development also supports the broader goals of allowing humans to enter, live, and work effectively in space. Examples of technology developments suitable for this solicitation are: improvements in sensor devices, improvements in superconducting technology, development of flight qualified laser cooling technology, and development of improved time standards.

V. UNDERGRADUATE STUDENT RESEARCH OPPORTUNITIES

Active research experience is one of the most effective techniques for attracting talented undergraduates to and retaining them in careers in mathematics, science, and engineering. The undergraduate years are critical in the educational sequence, as career-choice points and as the first real opportunities for in-depth study. MSAD is endeavoring to foster the career development of undergraduate students by offering optional supplements of approximately $5,000 per student to approved research tasks for undergraduate student research projects. This supplement may be requested for each year of the proposed research. These projects should involve undergraduate students in a meaningful way in ongoing research programs or in related sub-projects specifically designed for this purpose.

The proposals for the undergraduate student research projects should include: the nature of the student activities, presenting plans that will ensure the development of student-faculty and student-student interaction and communication; a concise description of the experience and record of the Principal Investigator and any potential advisors of students; and the criteria for evaluating the success of the project. Proposals for up to about two students should be a separate section (see information on proposal formatting in Section VII, subsection B) of about two pages per student and will not be counted against the maximum page limit. This effort should be shown as a separate line in the budget summary for each year.

The review criteria (in addition to those indicated in Appendix A, Section X, subsection B) for the supplements will be:

1. The value of the educational experience for the student participants, particularly the appropriateness of the research projects(s) and the nature of student participation in these activities;

2. The quality of plans for student preparation, student mentoring and follow through designed to promote continuation of student interest and involvement in research;

3. The proposed arrangements for managing the project and how the project will be evaluated.

If selected for involvement in this program, investigators are required to submit reports on these activities in conjunction with reporting on the primary grant. In particular, reports should include information on the activities of each student, the degree of interaction with their mentors, the future career plans of the student (if known) and an evaluation of the project progress.

VI. EXPERIMENTAL APPARATUS AND FLIGHT OPPORTUNITIES

A. EXPERIMENTAL APPARATUS

In order to address aspects of the research described in Section III, a number of pieces of flight hardware either have been developed or are being developed by NASA. To date, all of the development effort has focused on supporting the relatively mature community in condensed matter and low temperature physics. Existing flight hardware apparatus are described in Appendix B, Section I. NASA also is planning the development of new research capabilities to support all 3 sub-discipline areas of microgravity fundamental physics. Planned flight hardware apparatus are described in Appendix B, Section II. Section III of Appendix B lists the ground-based facilities that are available to support definition studies.

B. DIAGNOSTIC MEASUREMENTS

The capability to characterize science experiments in reduced gravity is essential to scientific progress in this program. NASA, in ground-based and reduced gravity studies, is developing techniques for enhancing imaging and visualization, and improving measurements of temperature and pressure. As these techniques mature, those most required by investigators will be reviewed for space flight development as part of the future flight equipment capability.

C. FLIGHT OPPORTUNITIES

Flight opportunities available for this program may include several Shuttle missions starting in 2000, missions aboard the Russian Mir space station, missions on the International Space Station (ISS) after 2000, and missions on free flying platforms after 2000.

Early flight opportunities under this NRA will be on the Space Shuttle with experimental apparatus being either in the Spacelab or mid-deck, which both allow astronaut interaction, or in the cargo bay. Residual acceleration levels on the order of 10^{-4} g are available in the Shuttle for limited periods of time. Space Shuttle flights range from 7 to 16 days in duration. The Space Acceleration Measurement System (SAMS) is expected to be available to measure and record actual accelerations at or near the apparatus for both Shuttle and ISS experiments. Considerable additional information on the Shuttle accommodations and capabilities can be found in the STS Investigators' Guide (see Bibliography). Experimental apparatus for the early utilization of the Space Station will primarily be in facilities such as the Glovebox and EXPRESS rack (ISS versions of Shuttle middeck class experiments). The Low Temperature Microgravity Physics Facility (LTMPF) is expected to be available for use in the late 2003 time frame after the completed assembly of the ISS. A high-capacity communications network supports Shuttle and ISS payload operations. Downlink channels enable users to monitor their instrument status and science data streams in real time. An uplink channel enables them to act on that information.

D. EXPERIMENT DEFINITION AND FLIGHT ASSIGNMENT PROCESS

Ground-based research is usually necessary to clearly define flight experiment objectives. This research may involve experimentation in NASA-provided ground-based facilities, including those which can provide a limited duration low-gravity environment. (These facilities are described in Appendix B, Section III.) Successful proposals for flight opportunities will be supported for a ground-based definition phase before review for flight assignment. The amount of support (technical, scientific, and budgetary) and the length of the definition period (usually from 6 months to 2 years) will depend on the specific investigator needs and the availability of resources from NASA. However, in preparing their budget plan for this research announcement, all respondents should estimate their annual costs for four years.

A flight experiment represents a considerable investment of resources, both human and financial. The Principal Investigator for a flight investigation in definition phase has the responsibility to continue the pursuit of basic knowledge which will make a flight experiment fully meaningful, and, in addition, will be responsible for major contributions to the large effort needed to define and build the flight experiment. In the first six months following selection, the Principal Investigator will meet with NASA representatives to discuss any technical feasibility issues related to the proposed flight experiment. These discussions will also include identification of resources needed to establish feasibility, produce a draft Science Requirements Document (SRD), conduct a Science Concept Review (SCR) of the flight experiment, and conduct the Requirements Definition Review (RDR) roughly one year after the SCR. Successful completion of these reviews will be required before the investigation will be approved for flight. It may be decided as a result of these discussions that the project should revert to ground-based status. This will not in any way preclude the PI's opportunities to propose for renewal of the research effort as a ground-based investigation, or to propose a flight experiment at a later date. The period of performance will be unchanged; the duration of support for the project will be as indicated at selection.

1. Near-Term Flight Opportunities. Successful proposals for use of the existing instruments will be funded for a period of advanced definition work, after which time the investigator will generate a detailed Science Requirements Document. The SRD, a detailed experiment description outlining the specific experiment parameters and conditions, as well as the background and justification for flight, must be prepared jointly by a NASA-appointed Project Scientist and the Principal Investigator and is then submitted to peer review. This formal review by both science and engineering panels will determine whether space flight is required to meet the science objectives. and whether instrument capabilities can be provided to meet the science requirements. Following approval by the panels, and subject to program resources, continuation support will be awarded and the flight facility hardware will be modified to meet the science requirements. NASA does not guarantee that any experiment selected for definition will advance to flight experiment status.

Investigations with unresolved science or engineering issues at the review of the SRD may be placed in ground-based status with support of limited duration (normally from one to three years), and asked to submit a proposal to a subsequent solicitation for further support.

2. Future Flight Opportunities. Successful proposals for the development of new apparatus will be funded for a period of definition. The length of the definition period will be based on the experiment requirements, but will generally be from 6 to 24 months. At the end of the experiment definition phase, the investigator will generate a detailed SRD. Following successful peer review of the science concept by science and engineering panels, the experiment will proceed into flight development and be considered for flight. As with opportunities for existing instruments, NASA does not guarantee that any experiment selected for definition will advance to flight development status, and the possibility exists that investigations may be placed in ground-based status, with continuing support from NASA for a limited period. In fact, to ensure that the highest quality experiments are flown in space, MSAD will strive toward selecting, on the average, up to two experiments for flight definition for each experiment that will actually fly.

Investigations with unresolved science or engineering issues at the review of the SRD may be placed in ground-based status with support of limited duration (normally from one to three years), and asked to submit a proposal to a subsequent solicitation for further support.

3. Ground-Based Definition Opportunities. Promising proposals for experimental research which are not mature enough to allow development of a Science Requirements Document after two years of definition, and proposals for development of theory in areas of current or potential microgravity experiments, may be selected for support in the MSAD Research and Analysis (R&A) Program. R&A studies are funded for periods of up to four years. A new proposal to a future

announcement is required in order to be selected for a flight opportunity or to continue R&A studies if appropriate.

VII. PROPOSAL SUBMISSION INFORMATION

This section gives the requirements for submission of proposals in response to this announcement. The research project described in the typical proposal submitted under this announcement must be directed by a Principal Investigator who is responsible for all research activities and may include one or more Co-Investigators. Proposers must address all the relevant selection criteria in their proposal as described in Section X and must format their proposal as described in this section. Additional general information for submission of proposals in response to NASA Research Announcements may be found in Appendix C.

A. LETTER OF INTENT

Organizations planning to submit a proposal in response to this NRA should notify NASA of their intent to propose by electronically sending a Letter of Intent (LOI) via the MSAD Web Page:

http://microgravity.msad.hq.nasa.gov/

Alternatively, Letters of Intent may be submitted via e-mail to the following address: loi@hq.nasa.gov

If electronic means are not available, you may mail Letters of Intent to the address given for proposal submission in the following section. Facsimile transmission of the Letter of Intent is also acceptable. The MSAD fax number is (202) 358-3091.

The Letter of Intent, which should not exceed two pages in length, must be typewritten in English and must include the following information:

- The potential Principal Investigator (PI), position, organization, address, telephone, fax, and e-mail address.
- A list of potential Co-Investigators (Co-I's), positions, and organizations.
- General scientific/technical objectives of the research.
- Intent to participate in the Undergraduate Student Research Opportunities, if appropriate.
- The equipment of interest listed in this NRA, if appropriate.

The Letter of Intent should be received at NASA Headquarters no later than January 27, 1997. The Letter of Intent is being requested for informational and planning purposes only, and is not binding on the signatories. Institutional authorizations are not required. The Letter of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. In the Letter of Intent, investigators may request more detail on the capabilities of the specific equipment (Appendix B) that might be used to accomplish their scientific objectives and/or items listed in the Bibliography (Appendix A, Section XI).

B. PROPOSAL

The proposal should not exceed 20 pages in length, exclusive of appendices and supplementary material, and should be typed on 8-1/2 x 11 inch paper with a 10- or 12-point font. Extensive appendices and ring-bound proposals are discouraged. Reprints and preprints of relevant work will be forwarded to the reviewers if submitted as attachments to the proposal.

The guidance in Appendix C, Section 8 regarding the content of renewal proposals is not applicable to this NRA. Renewal proposals should not rely on references to previous proposals for any information required for a complete proposal.

Fifteen copies of the proposal must be received at NASA Headquarters by March 25, 1997, 4:30 PM EDT to assure full consideration. Treatment of late proposals is described in Appendix C. Send proposals to the following address:

Dr. Mark C. Lee
NASA c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-03)
300 D Street, S.W.
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA can not receive deliveries on Saturdays, Sundays or federal holidays.

Proposals submitted in response to this Announcement must be typewritten in English and contain at least the following information (in addition to the required information given in Appendix C) in the format shown below:

- Title Page
- Table of Contents
- Executive Summary (replaces abstract) (1-2 pages)
- Research Project Description containing the following elements:
  - Statement of the hypothesis, objective, and value of this research.
  - Review of relevant research.
  - Justification of the need for low gravity to meet the objectives of the experiment.
  - Description of the diagnostic measurements that would be required to satisfy the scientific objectives of any proposed low gravity experiments.
  - Estimation of time profile of reduced-gravity levels needed for the experiment or series of experiments.
  - A clear and unambiguous justification of the need to perform the experiment in space as opposed to ground-based reduced-gravity facilities.
  - A description of a ground-based testing program that might be needed to complete the definition of the space flight experiment requirements in terms of experiment conditions, acceleration levels and duration, control and diagnostic measurement requirements, etc.
  - Sufficient technical detail about the proposed investigation to allow evaluation by NASA of technical feasibility and cost, including evaluation of compatibility of the proposed investigation with existing or planned flight hardware.
- Undergraduate Student Research Opportunity (not counted as part of the 20 page limit)
- Management plan appropriate for the scope and size of the proposed project, describing the roles and responsibilities of the participants
- Prior Period of Support
  - For proposals for renewal of ongoing MSAD-sponsored projects, a summary of the objective and accomplishments of the prior period of support.
- Appendices:
  - Budget plan estimating annual costs for four years. There should be at least one page for each of the four years and one page summarizing the total four-year budget. The information desired is explained below.
  - Summary of current and pending support for the Principal Investigator and Co-Investigators.
  - Complete current curriculum vita for the Principal and Co-Investigators, listing education, publications, and other relevant information necessary to assess the experience and capabilities of the senior participants.

- Signed Certifications (see below).

- **3.5 inch computer diskette containing electronic copy of Principal Investigator's name, address, complete project title, and executive summary**

The title page must clearly identify the research announcement to which the proposal is responding, title of the proposed research, Principal Investigator, institution, address and telephone number, total proposed cost, proposed duration, and must contain all signatories.

The executive summary should succinctly convey, in broad terms, what it is the proposer wants to do, how the proposer plans to do it, why it is important, and how it meets the requirements for microgravity relevance. The executive summary replaces the proposal abstract.

Each proposal should include the Solicited Proposal Application (Form A). Those requesting financial support should also include: Detailed Budget for 12-Month Period Direct Costs Only (Form B) for each year of funding; Budget for Entire Project Period Direct Costs Only (Form C); signed Certifications regarding Drug-Free Workplace Requirements (Form D); Debarment, Suspension and other Responsibility Matters (Form E); Lobbying (Form F). Copies of these forms may be found at the end of this document.

1. Proposal Cost Detail Desired. Sufficient proposal cost detail and supporting information will facilitate a speedy evaluation and award. Dollar amounts proposed with no explanation (e.g., Equipment: $58,000, or Labor: $10,000) may cause delays in evaluation or award. The proposed costing information should be sufficiently detailed to allow the Government to identify cost elements for evaluation purposes. Generally, the Government will evaluate cost as to reasonableness, allowability, and allocatability. Enclose explanatory information, as needed. Each category should be explained. Offerors should exercise prudent judgment as the amount of detail necessary varies with the complexity of the proposal.

VIII. NRA FUNDING

The total amount of funding for this program is subject to the annual NASA budget cycle. The Government's obligation to make awards is contingent upon the availability of appropriated funds from which payment for award purposes can be made and upon the receipt of proposals which the Government determines are acceptable for an award under this NRA.

For the purposes of budget planning, we have assumed that the Microgravity Science and Applications Division will fund up to five flight experiment definition proposals. These definition-phase proposals will be funded at a level not to exceed $200,000 per year. Approximately 15 ground-based study proposals will be funded, at an average of $100,000 per year, for up to 4 years. Resources permitting, a few high-risk, high-payoff-if-successful ideas will be considered for funding at an average level of $50,000 per year for up to two years. The initial fiscal year (FY) funding for all proposals will be adjusted, if required, to reflect partial fiscal year efforts. The proposed budget for ground-based studies should include researcher's salary, travel to science and NASA meetings (for a flight investigation, roughly one meeting every quarter with NASA or JPL should be anticipated, though travel activity will vary over the development of the experiment), other expenses (publication costs, computing or workstation costs), burdens, and overhead. During subsequent years, NRAs similar to this NRA will be issued, and funds are planned to be available for additional investigations.

IX. GUIDELINES FOR NON-U.S. PARTICIPATION

NASA accepts proposals from all countries, although this program does not financially support Principal Investigators in countries other than the U.S. Proposals from non-U.S. entities should not include a cost plan. Non-U.S. proposals and U.S. proposals which include non-U.S. participation, must be endorsed by the appropriate government agency in the country from which the non-U.S. participant is proposing. Such endorsement should indicate:

1. The proposal merits careful consideration by NASA.
2. If the proposal is selected, sufficient funds will be made available, from the country from which the non-U.S. participant is proposing, for their participants to undertake the activity as proposed.

Special instructions apply to non-U.S. proposals. In addition to sending the original proposal (and copies) to Dr. Mark C. Lee at NASA through Information Dynamics Inc. as directed above, one (1) additional copy along with the Letter of Endorsement must be forwarded to NASA, in time to arrive before the deadline established for this NRA:

Ms. Ruth Rosario
ref: NRA-96-HEDS-03
Space Flight Division
Code IH
National Aeronautics and Space Administration
Washington, DC 20546-0001
USA

All proposals must be typewritten in English. All non-U.S. proposals will undergo the same evaluation and selection process as those originating in the U.S.

Sponsoring non-U.S. agencies may, in exceptional situations, forward a proposal directly to the above address if review and endorsement is not possible before the announced closing date. In such cases, NASA's Office of External Relations Space Flight Division should be advised when a decision on endorsement can be expected.

Successful and unsuccessful proposers will be notified by mail directly by the NASA program office coordinating the NRA. Copies of these letters will be sent to the sponsoring government agency. Should a non-U.S. proposal or U.S. proposal with non-U.S. participation be selected, NASA's Office of External Relations will arrange with the non-U.S. sponsoring agency for the proposed participation on a no-exchange-of funds basis, in which NASA and the appropriate government agency will each bear the cost of discharging its respective responsibilities. Depending on the nature and extent of the proposed cooperation, these arrangements may entail:

1. A letter of notification by NASA; and
2. An exchange of letters between NASA and the sponsoring government agency.
3. An agreement or memorandum of understanding between NASA and the sponsoring government agency.

X. **EVALUATION AND SELECTION**

A. EVALUATION PROCESS.

The evaluation process for this NRA will begin with a scientific and technical peer review of the submitted proposals. NASA will conduct an engineering review of the potential hardware requirements for proposals that include flight experiments. The programmatic objectives of this NRA, as discussed in the introduction to this Appendix, will be applied by NASA to enhance program breadth, balance, and diversity. NASA will also evaluate the cost of the proposal. For proposals seeking to enter flight definition status, NASA will also evaluate the implementation management approach, including the cost basis, the risk mitigation plans, and the experience of the implementing organization. Upon completion of deliberations, offerors will be notified regarding proposal selection or rejection. Offerors whose proposals are declined will have the opportunity of a verbal debriefing with a NASA representative regarding the reasons for this decision. Additional information on the evaluation and selection process is given in Appendix C.

B. EVALUATION FACTORS.

The following section replaces Section 13 of Appendix C.

The principal elements considered in the evaluation of proposals solicited by this NRA are: relevance to NASA's objectives, intrinsic merit, and cost. Of these, intrinsic merit has the greatest weight, followed by relevance to NASA's objectives, which has slightly lesser weight. Both of these elements have greater weight than cost. Evaluation of the intrinsic merit of the proposal includes consideration of the following factors, in descending order of importance:

1. Overall scientific or technical merit, including evidence of unique or innovative methods, approaches, or concepts, the potential for new discoveries or understanding, or delivery of new technologies/products and associated schedules;
2. Qualifications, capabilities, and experience of the proposed Principal Investigator, team leader, or key personnel who are critical in achieving the proposal objectives;
3. Institutional resources and experience that are critical in achieving the proposal objectives;
4. Overall standing among similar proposals available for evaluation and/or evaluation against the known state-of-the-art.

Evaluation of the cost of a proposed effort includes consideration of the realism and reasonableness of the proposed cost, and the relationship of the proposed cost to available funds.

XI. **BIBLIOGRAPHY**

Technical background material is available to NRA proposers upon written request to:

Dr. Ulf Israelsson
Mail Stop 79-3,
Space Sciences Flight Experiment Program Office
Jet Propulsion Laboratory
4800 Oak Grove Drive,
Pasadena, CA 91109

Documents that may provide useful information to proposers are listed below:

1. Microgravity Science and Applications Division, on the World Wide Web: http://microgravity.msad.hq.nasa.gov

2. Microgravity Science and Applications Apparatus and Facilities, NASA Marshall Space Flight Center.

3. STS Investigators' Guide, NASA Marshall Space Flight Center.

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APPENDIX B
TO NRA-96-HEDS-03

HARDWARE AND FACILITY DESCRIPTIONS

The Microgravity Science and Applications Division (MSAD) is pursuing a program for the development of Space Shuttle and early International Space Station (ISS) payloads that can be configured (or reconfigured) to accommodate multiple users. This evolutionary program is expected to meet the science requirements of increasingly sophisticated microgravity investigations and to permit the eventual development of experiment payload technologies for research throughout the era of the ISS.

MSAD is also developing plans to support a small number of investigators in need of the exceptionally quiet gravity environment aboard a free flying platform. These are primary in the sub-discipline of gravitational and relativistic physics.

I. CURRENT FLIGHT HARDWARE

The experimental apparatus described in this section are under development for flight on a series of Space Shuttle missions, primarily to support experiments in condensed matter Physics and low temperature physics. Some of these apparatus (such as the Glovebox) may also be suitable for use by experiments in Laser Cooling and Atoms Physics. NASA anticipates several additional flight opportunities for investigations capable of using this hardware beginning in 2001. Minor modifications of the current hardware may be possible to make it more versatile and to accommodate users and experiments other than those for which it was originally designed. Several potential enhancements are highlighted in the descriptions for the current hardware. Availability of the instruments described here, with or without modification, is contingent upon the availability and allocation of resources, and cannot be guaranteed at this time.

More detailed descriptions of the current flight hardware may be requested in the Letter of Intent described in Appendix A, Section VII.

A. LOW TEMPERATURE PLATFORM (LTP)

The Low Temperature Platform is a multidisciplinary experimental flight facility dedicated to low temperature research investigations. LTP last flew as part of the USMP-1 mission in October, 1992. It carried the Lambda Point Experiment, which measured the heat capacity of helium immediately below the superfluid transition with 100 times better resolution than possible on the ground. The next flight of the facility is scheduled for October 1997 as part of the USMP-4 mission when it will carry the Confined Helium Experiment to investigate the effects of confinement to a 50 micron dimension on the properties of helium.

LTP is a cryostat that accommodates up to 31.5 kilograms of instrumentation inside a volume filled with enough liquid helium to maintain the experiment as cold as 1.6 Kelvin for a 14-day lifetime with an experiment heat load of about 10 mW. The ambient magnetic field is minimized by a magnetic shield around the cryostat, and local accelerations can be monitored by the Space Acceleration Measurement System (SAMS). The LTP interface system can provide both on-orbit recording of data and transmission of experiment data back to Earth in real time. Commanding of the data-gathering sequence is also possible in near real time. For the USMP missions, LTP is bolted to the top of a Mission Peculiar Experiment Support Structure (MPESS), while the supporting electronics are attached to cold plates on the forward bulkhead of this structure.

A detailed description of the capabilities of LTP is available upon request.

B. LTP INSTRUMENT CAPABILITIES

The next STS based flights for this facility are scheduled for October 1997 when it will carry the Confined Helium Experiment (CHeX) and on February 2001 when it will support the Critical Dynamics In Microgravity Experiment (DYNAMX). CHeX, flying as part of the USMP-4 science payload, will investigate the effects of confinement on the properties of helium and DYNAMX, flying as part of the Microgravity Science Payload (MSP-1), will study dynamic critical-point phenomena driven away from equilibrium by a heat current.

The CHeX and DYNAMX science instruments will be installed in the LTP. The instruments contain high resolution thermometry for measurement of the helium temperature at unprecedented resolution. The CHeX calorimeter is a cylindrical vessel with an internal volume of about 30 ml constructed of high conductivity copper. Confinement to a helium sample size of about 50 microns is accomplished by stacked silicon discs. The DYNAMX thermal conductivity cell is made from very low conductivity material and is about 2 cm in diameter and 1 cm long. Thin side-wall thermometer rings make contact to the helium through the low conductivity walls of the cell. The instrument thermal control system is constructed to enable measurements between 1.8 K and 2.5 K at a stability of $\pm$ 10 nK. The pressure of the helium sample is held at saturated vapor pressure by means of a small bubble in a separate chamber.

Temperature measurements are facilitated through the use of high resolution thermometers (HRT) and germanium resistance thermometers. The HRTs take advantage of superconducting SQUID technology and have a resolution and drift of 0.1 nK and 0.1 pK/sec, respectively. The HRTs can operate at a sampling rate up to 100 Hz.

Analog experiment control is performed by means of a Main Electronics Assembly, which is controlled by an autonomous sequence resident in a R3000 computer.

C. GLOVEBOX

The overall philosophy of the Glovebox program is to provide the ability to conduct smaller, less complex science experiments or technology demonstrations in a microgravity environment in a faster, better, and cheaper manner. The hardware development cycle runs approximately 2-3 years. The Glovebox is intended to be used a generic platform for conducting a wide range of experiments. It is especially well suited for experiments that require containment of materials, both fluid and solid. Experiments developed for the Glovebox are expected to be relatively small and self-contained yet can be of a sophisticated nature using state of the art diagnostics. Various services are available in the Gloveboxes including power, video, still photography, a laptop computer for experiment control and data acquisition, and cleaning supplies. In general these experiments are less automated and require significant crew involvement in their operation and in the scientific decision making process. At this time, 12 Glovebox Investigations in the disciplines of materials science, fluid physics, biotechnology, and combustion science are under development. Several versions of Gloveboxes have been flown on the Shuttle Spacelab and Middeck as well as the Russian Mir Space Station. A Microgravity Science Glovebox for the International Space Station is currently under development.

The Middeck Glovebox (MGBX) facility is an enclosed volume that provides physical isolation of various experiments from the middeck and enables crew member manipulation of these experiments through gloveports. The MGBX provides containment of powders, splinters, liquids, flames, or combustion products which may be produced from experiment operations. The MGBX occupies two standard lockers in the space shuttle middeck. The MGBX door opening to insert or retrieve experiment hardware is about 20.3 cm by 19.4 cm. The working volume is about 35 liters and is approximately 45 cm wide, 30 cm deep, and 25 cm high.

An air filtering system protects the middeck environment from experiment products. Forced air cooling can withdraw a maximum of 60 watts of experiment generated heat. Up to 60 watts of experiment power can be provided via a protected 28 VDC line. A power converter box is also available which can provide +24, +5, +12, and -12 VDC lines.

The MGBX can be used in various modes of pressure and air circulation. The working area can serve as a sealed environment that is isolated from the crew cabin atmosphere, as a constantly recirculating atmosphere that is maintained at a pressure slightly lower than the middeck ambient, or as a working area open to the middeck. Airtight gloves or non-sealed cuffs are mounted in the two gloveports. Multipurpose filters remove particles, liquids, and reaction gases from the recirculated air. Pressure, humidity, and temperature sensors are utilized to monitor filter performance.

Video and 35 mm cameras are the primary method utilized for gathering data. The MGBX has three CCD video cameras. The camera control electronics are contained within the MGBX, while the camera heads can be mounted external to the MGBX and positioned to view through the specialized video ports, or through the large window on top of the MGBX. The videoports allow the camera heads to swivel to view the entire working area. Both black and white and color videocameras are available. Three video recorders provide data storage, with digital data stored in the audio channels (up to three audio and three discrete channels of data can be recorded). Due to limitations of the Space Shuttle middeck, there is no standard data or video downlink. There is the possibility of some near real-time video downlink (from the Shuttle Camcorder), but this will be determined on a mission-by-mission basis. Adjustable lighting, video port plugs, a backlight panel, a halogen flashlight, and a stray light window cover provide different photographic options.

D. LASER LIGHT SCATTERING HARDWARE

A versatile, miniature, modular light scattering instrument has been developed at NASA Lewis Research Center for use in microgravity. Development of an enhanced multiangle Laser Light Scattering (LLS) facility is underway. LLS can be used to measure microscopic particles in the size range from 30 angstroms to above three microns. It is a non-invasive technique which can determine particle structure, weight-average molecular weight, and particle-particle interactions. This technique is also appropriate for studying spinodal decomposition, aggregation, diffusive transport, and critical phenomena. Design and development of flight hardware for accommodation in the EXPRESS rack on Spacelab have already been started. The hardware will be capable of making static and dynamic light scattering measurements. Specific capabilities include: Bragg diffraction and photon counting from 10° to 170° with 0.25° resolution; small angle scattering from 0.10° to 10° with 0.25° resolution; Bragg scattering from 10° to 60°; and ability for sample rotation and oscillation. Flight hardware for use on the ISS is in the planning phase.

E. CRITICAL FLUID LIGHT SCATTERING INSTRUMENT (CFLSI)

The CFLSI is a single sample facility. It was developed by the University of Maryland for the Space Shuttle cargo bay Mission Peculiar Support Structure (MPESS) carrier.

CFLSI allows thermal control at temperatures near 290 K stable to less than 3 µK for 5 hours with 1 µK/cm thermal gradients. The fluid volume can be on the order of 1 cm^3. The thermal control range is roughly 283-298 K, and the thermostat relaxation time is 1-2 minutes for < 10 mK steps and as much as 30 minutes for > 1K steps.

The thermostat is a multishell cylinder with optical end windows for dynamic light scattering angles of approximately 12 and 168 degrees. It uses two photomultipliers and two logarithmic time base correlators. There are two possible light paths through the cell that may be equal or unequal in their intensity. Transmission intensity is recorded by photodiodes with 16 bit A/D and one bit noise floor. The instrument supports real-time data down-link and command up-link during the mission. (There is a passive vibration isolation system that can isolate the instrument from Shuttle g-jitter over the frequency range form 10 Hz to a few hundred Hz.)

F. CRITICAL POINT FACILITY (CPF)

The CPF is a European Space Agency-developed multiuser facility. It is currently configured for operations inside a Spacelab module on board the Space Shuttle. Its first flights were on the

International Microgravity Laboratories -1 and -2, launched in January 1992 and July 1994. The missions conducted multiple experiments, with operational time shared sequentially among them.

The heart of CPF is a 5 kilogram cylindrical thermostat, unique to each experiment. The thermostat's inner-most shell is an 11 cm long by 6 cm diameter sample cell unit with two optical planes through it (one at 30 cm and the other at 90 cm from one end of the cylinder). One optical plane supports an integral Twyman-Green interferometer. The other optical plane supports full field visualization, light transmission, and angle-dependent static light scattering. Thermistor leads and experiment specific electrical leads are connected to the sample cell units as provided by NASA or its PIs. Fluid stirring, local cell heating, DC electric fields, and piezoelectric transducers have been supported to date.

The operating temperature control range is 303-343 K with a temperature stability of $\pm$ 50 microK. Temperature steps, ramps, or quenches of 0.1 mK or larger are permitted. A CCD video camera and a 35 mm still camera record images of a selected cell or optical path. The video is down-linked to the ground continuously at a rate of one frame every six seconds. Real-time video is possible for limited times using Shuttle resources. Temperature data comes at 1 Hz. Upgrades based on science requirements may be possible, for example dynamic light scattering and high resolution phase shifting interferometry.

G. ANALYSE DES LIQUIDES CRITIQUES DANS L'ESPACE (ALICE-II)

This hardware is used for the study of transport phenomena and hydrodynamic instabilities in near critical fluids under variable gravity conditions. Optical means are mainly used to explore a fluid which is controlled around its critical temperature. The fluids are contained within two 1 cm^3 sample cells mounted within 12 mm diameter windows which allow the diagnostic beams to reach the fluid under study. One of the two cells is equipped with a Mach Zender Interferometer. The two cells are set on a sample cell holder system located within a high precision thermostat which provides for reaching and maintaining the required temperature with a high degree of stability. The sample cells are installed in the thermostats before launch. During each mission the required number of thermostats are placed successively in ALICE II by a crew member and may undergo one or several experimental cycles, lasting 48 to 96 hours, and is defined before the flight by means of a cassette installed in the instrument. The data are comprised of video images and of scientific and technological parameters. The images are recorded on HI-8 type video cassettes and one is needed for each experimental cycle. The numerical data are recorded on PCMCIA cards or the programming cassette.

The response of the near critical fluid to calibrated temperature ramps and heat pulses, given by a thermistor, are explored by the means of the following diagnostic equipment: transmissivity measurement, small angle scattering, interferometry, full field observation, grid shadow graph, and microscopic observation. Typical fluid working temperatures are 30-70 C with a temperature stability of about 40μK/hour. Quench capability is also included.

H. CRITICAL FLUID VISCOSITY EXPERIMENT (CVX)

The CVX is being built to measure the viscosity of xenon near its critical point. It uses an oscillating screen viscometer, developed specifically for the flight experiment. Viscosity measurements can be performed with an accuracy of 0.2 % between 60 mK to 600 microK from Tc. The sample loading is within 0.3 % of the critical density for a roughly 10 cm^3 volume cell. Temperature gradients are less than 0.22 microK/cm. The thermostat is capable of controlling temperature to ± 30 microK for 5 hours.

II. **FUTURE DIRECTIONS**

The evolving focus of the MSAD flight program emphasizes the development of modular payloads that can be configured (or easily reconfigured) to accommodate multiple users. In anticipation of this evolution in experimental hardware, NASA has developed descriptions of hardware capabilities perceived as suitable for the research described in Appendix A. Future hardware, now in the early concept definition stage, could, if developed, be available for flights in 2000 and beyond.

These general hardware capabilities descriptions are included as point-of-departure for researchers to consider the type of capabilities that might meet their science requirements; researchers should not, however, feel limited by these capabilities. The descriptions are concepts for guidance only; NASA has made no commitments to develop this hardware. The proposals received in response the this NRA will be used to more accurately determine the capabilities needed in future flight hardware.

A. LOW TEMPERATURE MICROGRAVITY PHYSICS FACILITY (LTMPF)

Definition for a LTMP Facility for the International Space Station has begun at the Jet Propulsion Laboratory. This facility will provide frequent low-cost access to space for long duration cryogenic fundamental physics experiments. A 270-liter dewar will provide 3 months of on-orbit experimentation time each for two instruments operating as an attached payload in Earth orbit with a selectable helium bath temperature of 1.8 to 2.05 Kelvin. Each cryogenic instrument insert may weigh 30 Kg and is constrained in size to a cylinder 20 cm diameter by 45 cm long. Provisions for instrument power, electronic and software control, near real time telemetry and command, vibration isolation, radiation and acceleration environment monitors and telescience operation from investigators' home facilities will be provided by LTMPF. The facility will provide an acceleration environment of 10^{-6} g during planned microgravity periods and 10^{-4} g at all other times. Microgravity stable periods will occur for 30 days, five times each year. The facility is planned to fly every two years with the first flight in 2003. JPL will support experimenters with the flight instrument build, instrument integration and test with the facility, environmental test, delivery to KSC, the launch campaign and planning and the conduct of flight operations.

Investigators using the LTMPF are encouraged to combine objectives into compatible multiple experiments suitable for conduct within a single instrument to further enhance the science return for the dollars expended.

B. FREE FLYING PLATFORM (FFP).

The FFP is primarily intended to support select experiments in Gravitational and Relativistic Physics. A design for the FFP will be developed in concert with successful investigations selected from this announcement. The requirements for the FFP will be derived from the Science Requirements of the selected investigation(s).

C. MICROGRAVITY SCIENCE GLOVEBOX (MSG)

The MSG on the ISS will be a larger version of the Middeck Glovebox described above. The MSG will have a larger work area to allow larger size and mass experiments to be conducted inside the Glovebox. The MSG will provide up to 1000 watts of experiment power, a vent connection, a nitrogen connection, an airlock, illumination, color and black and white video cameras and recorders for viewing, recording, or downlinking, and miscellaneous tools and cleaning supplies. The MSG will be developed by the European Space Agency and will be available for use soon after the deployment of the US Laboratory Module of the ISS. The MSG may be suitable for some experiments in Condensed Matter Physics and some experiments in Laser Cooling and Atomic Physics.

D. EXPRESS RACK FACILITY (ERF)

The ERF is a multi-user facility that provides simplified, standard payload interfaces for Space Station payload integration thus reducing development time for the experiment developer. The ERF is envisioned to have greater mass, volume, power and data capabilities than the MSG. It can accommodate existing payloads and add more experiments to the user community. There are two

ERF configurations. One is the 8 middeck lockers and 2 Standard Interface Rack (SIR) drawers. The other configuration is 15 SIR drawers.

The ERF can provide accommodations for small and medium sized payloads, provide simple standard hardware and software interfaces, and also provide for simple and streamlined integration. The ERF hardware data are required to be displayed on-orbit and down linked, both in real-time and non-real-time. The ERF may be suitable for some experiments in Condensed Matter Physics and some experiments in Laser Cooling and Atomic Physics.

III. GROUND-BASED FACILITIES

Investigators often need to conduct reduced gravity experiments in ground-based facilities during the experiment definition and technology development phases. The NASA ground-based reduced gravity research facilities that support the MSAD fundamental physics program include two drop towers at the Lewis Research Center (LeRC) and a low-gravity aircraft.

A. 2.2-SECOND DROP TOWER

The 2.2 Second Drop Tower is a heavily utilized reduced gravity facility at LeRC that plays a key role in the support of Microgravity Science. It routinely supports over 1000 test drops per year (the daily test schedule allows up to 12 drops). The facility consists of a shop for experiment buildup, integration and testing; several small laboratories for experiment preparation and normal gravity testing; electronics support rooms and an eight story tower in which the drop area is located.
The Drop Tower at LeRC provides 2.2 second of low gravity test time for experiment packages with payload weights up to 139 kg. Rectangular experiment packages are dropped under normal atmospheric conditions from a height of 79 ft. Air drag on an experiment is minimized by enclosing it in a drag shield. A gravitational acceleration level of less than 10^{-4} g is obtained during the drop as the experiment package falls freely within the drag shield. The only external force acting on the falling experiment package is the air drag associated with the relative motion of the package within the enclosure of the drag shield. A drop is terminated when the drag shield and experiment assembly impact an air bag. The deceleration levels at impact have peak values of 15 to 30 g.

Data can be acquired by high-speed motion picture cameras as well as video cameras. Video signals are transmitted to remote video recorders via a fiber optic cable that is dropped with the experiment. Onboard data acquisition and control systems also record data supplied by instrumentation such as thermocouples, pressure transducers, and flowmeters.

B. 5.18-SECOND ZERO-GRAVITY FACILITY

The 5.18-second Zero-Gravity Facility has a 132 meter free fall distance in a drop chamber which is evacuated by a series of pumpdown procedures to a final pressure of 1 Pa. Experiments with hardware weighing up to 300 kilograms are mounted in a one meter diameter by 3.4 meter high drop bus. Gravitational acceleration of less than 10^{-5} g is obtained. At the end of the drop, the bus is decelerated in a 6.1 meter deep container filled with small pellets of expanded polystyrene. The deceleration rate ramps up to 65 g (in 150 milliseconds). Visual data is acquired through the use of on-board, high-speed motion picture cameras and 8mm video recorders. Also, other data such as pressures and temperatures are recorded on board with various data acquisition systems. Deceleration data are transmitted to a control room by a telemetry system. Due to the complexity of drop chamber operations and time required for pump-down of the drop chamber, only one or two tests are performed per day.

C. PARABOLIC FLIGHT RESEARCH AIRCRAFT

The parabolic research aircraft can provide up to 40 periods of low gravity for up to 25-second intervals each during one flight. The aircraft accommodate a variety of experiments of different sizes and is often used to refine space flight experiment equipment and techniques and to train crew members in experiment procedures, thus giving investigators and crew members valuable experience working in a weightless environment. The aircraft obtain a low gravity environment by flying a parabolic trajectory. Gravity levels twice those of normal gravity occur during the initial and final portions of the trajectory, while the brief pushover at the top of the parabola produces less than one percent of Earth's gravity (10^{-2} g). The interior bay dimensions are approximately 3 meters wide and 2 meters high by 16 meters long. Several experiments, include a combination of attached and free-floated hardware (which can provide effective gravity levels of 10^{-3} g for periods up to 10 seconds) can be integrated in a single flight. Both 28 VDC and 100/115 VAC power are available. Instrumentation and data collection capabilities must be contained in the experiment packages.

D. JPL LOW TEMPERATURE GROUND FACILITIES.

Ground based facilities are available at JPL equipped with high resolution platforms similar to the CHeX and LPE flight instrument. Collaborations with JPL researchers are encouraged to aid in the transfer of technology to new investigators and other use of JPL resources. Prior to shipment of an experiment to Kennedy Space Center for integration with the STS, it must first be tested and flight-qualified with the LTP. Facilities for experiment integration with the LTP and functional testing of the complete system exist at JPL. Environmental testing and qualification for flight must also be performed for each flight experiment. JPL has test chambers and qualified personnel to perform vibration, acoustic, electromagnetic, and thermal vacuum tests, all of which are required prior to shipment of an experiment to KSC. Personnel at JPL are also available to assist investigators with the KSC preflight campaign and mission operations.

E. JPL FREQUENCY STANDARDS LABORATORY

Ground based facilities are available at JPL equipped with many requisite capabilities necessary for research in Laser Cooling and Atomic Physics. Potential investigators are welcomed to contact JPL to discuss potential collaborative efforts or to inquire about any potential assistance that can be provided.

F. JPL LOW-GRAVITY LIQUID HELIUM FACILITY

JPL also provides a liquid helium facility suitable for use on the low-gravity aircraft. This facility provides optical access to the sample. The sample volume is roughly a 10-cm-diameter cylinder, 2.5 cm long. Supporting electronics are provided with the facility which include video recording of the sample.

G. LOW-GRAVITY CELL.

JPL has developed a technique based on magnetostriction whereby pressure gradients induced by gravity in small helium samples can be removed to the 99 % level. The same facility can also be used to levitate large drops of helium.

H. CRITICAL FLUIDS CELL FLIGHT HARDWARE LAB.

This lab at LeRC has been used to build CPF or ALICE-like cells for the two IML shuttle missions. The lab is capable of designing, building, filling, and 1-g testing optical cells for liquid-vapor critical fluid experiments. Cells are assembled with interferometric requirements and filled to < 0.3 % of the critical density for a 0.1 cubic cm fluid volume with a tested leak rate as low as 3×10^{-10} std. cc/sec. Lab thermostats are capable of control to $\pm$ 0.4 mK for samples above room temperature. Interferometry and light transmission experimental tools are available also. The ZENO flight hardware will be set up and maintained in this lab when not in mission preparation.

IV. MICROGRAVITY FUNDAMENTAL PHYSICS DIAGNOSTIC/MEASUREMENT CAPABILITY

NASA has adapted or developed a number of diagnostic/measurement techniques for microgravity fundamental physics research. Some of these techniques, such as high resolution thermometry, SQUID readouts, and advanced thermal control systems, have already been successfully used in flight. Some techniques under development are described below.

A. HIGH RESOLUTION PRESSURE TRANSDUCER AND CONTROLLER.

NASA's Advanced Technology Development (ATD) program is sponsoring development of this device. It will be able to control and read pressure to better than one part in 10^{11} for pressures in the 1 to 30 bar range. The readout utilizes a niobium diaphragm which bulges slightly as the pressure in the sample cell is changed. The position of the diaphragm is sensed inductively with very high precision by use of a SQUID. To control pressure, an electrostatic force can be applied to push against the diaphragm.

B. MAGNETOSTRICTIVE ACTUATORS.

The ATD program is also sponsoring development of giant magnetostrictive materials for use as smart movers at low temperatures. Planned applications are for cold valves and heat switches.

APPENDIX C
NRA-96-HEDS-03

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS FOR SOLICITED PROPOSALS

(June 1995)

1. Foreword

a. These instructions apply to NASA Research Announcements. The "NASA Research Announcement (NRA)" permits competitive selection of research projects in accordance with statute while preserving the traditional concepts and understandings associated with NASA sponsorship of research.

b. These instructions are Appendix I to 1870.203 of the NASA Federal Acquisition Regulation Supplement.

2. Policy

a. Proposals received in response to an NRA will be used only for evaluation purposes. NASA does not allow a proposal, the contents of which are not available without restriction from another source, or any unique ideas submitted in response to an NRA to be used as the basis of a solicitation or in negotiation with other organizations, nor is a pre-award synopsis published for individual proposals.

b. A solicited proposal that results in a NASA award becomes part of the record of that transaction and may be available to the public on specific request; however, information or material that NASA and the awardee mutually agree to be of a privileged nature will be held in confidence to the extent permitted by law, including the Freedom of Information Act.

3. Purpose

These instructions supplement documents identified as "NASA Research Announcements." The NRAs contain programmatic information and certain requirements which apply only to proposals prepared in response to that particular announcement. These instructions contain the general proposal preparation information which applies to responses to all NRAs.

4. Relationship to Award

a. A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded in response to an NRA. NASA will determine the appropriate instrument.

b. Grants are generally used to fund basic research in educational and nonprofit institutions, while research in other private sector organizations is accomplished under contract. Contracts resulting from NRAs are subject to the Federal Acquisition Regulation and the NASA FAR Supplement (NHB 5100.4). Any resultant grants or cooperative agreements will be awarded and administered in accordance with the NASA Grant and Cooperative Agreement Handbook (NHB 5800.1).

5. Conformance to Guidance

a. NASA does not have mandatory forms or formats for preparation of responses to NRAs; however, it is requested that proposals conform to the guidelines in these instructions. NASA may accept proposals without discussion; hence, proposals should initially be as complete as possible and be submitted on the proposers' most favorable terms.

b. In order to be considered responsive, a submission must, at a minimum, present a specific project within the areas delineated by the NRA; contain sufficient technical and cost information to permit a meaningful evaluation; be signed by an official authorized to legally bind the submitting organization; not merely offer to perform standard services or to just provide computer facilities or services; and not significantly duplicate a more specific current or pending NASA solicitation.

6. NRA-Specific Items

a. Several proposal submission items appear in the NRA itself. These include: the unique NRA identifier; when to submit proposals; where to send proposals; number of copies required; and sources for more information.

b. Items included in these instructions may be supplemented by the NRA.

7. Proposal Contents

a. The following information is needed in all proposals in order to permit consideration in an objective manner. NRAs will generally specify topics for which additional information or greater detail is desirable. Each proposal copy shall contain all submitted material, including a copy of the transmittal letter if it contains substantive information.

b. **Transmittal Letter or Prefatory Material.**

(1) The legal name and address of the organization and specific division or campus identification if part of a larger organization;

(2) A brief, scientifically valid project title intelligible to a scientifically literate reader and suitable for use in the public press;

(3) Type of organization: e.g., profit, nonprofit, educational, small business, minority, women-owned, etc.;

(4) Name and telephone number of the Principal Investigator and business personnel who may be contacted during evaluation or negotiation;

(5) Identification of other organizations that are currently evaluating a proposal for the same efforts;

(6) Identification of the NRA, by number and title, to which the proposal is responding;

(7) Dollar amount requested , desired starting date, and duration of project;

(8) Date of submission; and

(9) Signature of a responsible official or authorized representative of the organization, or any other person authorized to legally bind the organization (unless the signature appears on the proposal itself).

c. **Restriction on Use and Disclosure of Proposal Information**

Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on the title page of the proposal and specify the information subject to the notice by inserting appropriate identification, such as page numbers, in the notice. In any event, information contained in proposals will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

NOTICE --- Restriction on Use and Disclosure of Proposal Information

The information (data) contained in [insert page numbers or other identification] of this proposal constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

d. **Abstract**

Include a concise (200-300 word if not otherwise specified in the NRA) abstract describing the objective and the method of approach.

e. **Project Description**

(1) The main body of the proposal shall be a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the broad design of experiments to be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in these instructions and any specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants

should be described. Subcontracting significant portions of a research project is discouraged.

(2) When it is expected that the effort will require more than one year for completion, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should, of course, be on the first year of work, and the description should distinguish clearly between the first year's work and work planned for subsequent years.

f. **Management Approach**

For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and arrangements for ensuring a coordinated effort should be described. Intensive working relations with NASA field centers that are not logical inclusions elsewhere in the proposal should be described.

g. **Personnel**

The Principal Investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch of the Principal Investigator, a list of principal publications and any exceptional qualifications should be included. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar biographical information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

h. **Facilities and Equipment**

(1) Describe available facilities and major items of equipment especially adapted or suited to the proposed project, and any additional major equipment that will be required. Identify any Government-owned facilities, industrial plant equipment, or special tooling that are proposed for use.

(2) Before requesting a major item of capital equipment, the proposer should determine if sharing or loan of equipment already within the organization is a feasible alternative. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for research and non-research purposes should be explained.

i. **Proposed Costs**

(1) Proposals should contain cost and technical parts in one volume: do not use separate "confidential" salary pages. As applicable, include separate cost estimates for salaries and wages; fringe benefits; equipment; expendable materials and supplies; services; domestic and foreign travel; ADP expenses; publication or page charges; consultants; subcontracts; other miscellaneous identifiable direct costs; and indirect costs. List salaries and wages in appropriate organizational categories (e.g., Principal Investigator, other scientific and engineering professionals, graduate students, research assistants, and technicians and other non-professional personnel). Estimate all manpower data in terms of man-months or fractions of full-time.

(2) Explanatory notes should accompany the cost proposal to provide identification and estimated cost of major capital equipment items to be acquired; purpose and estimated number and lengths of trips planned; basis for indirect cost computation (including date of most recent negotiation and cognizant agency); and clarification of other items in the cost proposal that are not self- evident. List estimated expenses as yearly requirements by major work phases. (Standard Form 1411 may be used).

(3) Allowable costs are governed by FAR Part 31 and the NASA FAR Supplement Part 18-31 (and OMB Circulars A-21 for educational institutions and A-122 for nonprofit organizations).

j. **Security**

Proposals should not contain security classified material. If the research requires access to or may generate security classified information, the submitter will be required to comply with - Government security regulations.

k. **Current Support**

For other current projects being conducted by the Principal Investigator, provide title of project, sponsoring agency, and ending date.

l. **Special Matters**

(1) Include any required statements of environmental impact of the research, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.

(2) Proposers should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting officer, when applicable.

8. Renewal Proposals

a. Renewal proposals for existing awards will be considered in the same manner as proposals for new endeavors. A renewal proposal should not repeat all of the information that was in the original proposal. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the research are expected to be covered during the period for which support is desired. A description of any significant findings since the most recent progress report should be included. The renewal proposal should treat, in reasonable detail, the plans for the next period, contain a cost estimate, and otherwise adhere to these instructions.

b. NASA may renew an effort either through amendment of an existing contract or by a new award.

9. Length

Unless otherwise specified in the NRA, effort should be made to keep proposals as brief as possible, concentrating on substantive material. - Few proposals need exceed 15-20 pages. Necessary detailed information, such as reprints, should be included as attachments. A complete set of attachments is necessary for each copy of the proposal. As proposals are not returned, avoid use of "one-of-a-kind" attachments: their availability may be mentioned in the proposal.

10. Joint Proposals

a. Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards would be made.

b. Where a project of a cooperative nature with NASA is contemplated, describe the contributions expected from any participating NASA investigator and agency facilities or equipment which may be required. The proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which specify the internal arrangements NASA will actually make are not acceptable as a means of establishing an agency commitment.

11. Late Proposals

A proposal or modification received after the date or dates specified in an NRA may be considered if the selecting official deems it to offer NASA a significant technical advantage or cost reduction.

12. Withdrawal

Proposals may be withdrawn by the proposer at any time. Offerors are requested to notify NASA if the proposal is funded by another organization or of other changed circumstances which dictate termination of evaluation.

13. Evaluation Factors

a. Unless otherwise specified in the NRA, the principal elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA's objectives, intrinsic merit, and cost.

b. Evaluation of a proposal's relevance to NASA's objectives includes the consideration of the potential contribution of the effort to NASA's mission.

c. Evaluation of its intrinsic merit includes the consideration of the following factors, none of which is more important than any other:

(1) Overall scientific or technical merit of the proposal or unique and innovative methods, approaches, or concepts demonstrated by the proposal.

(2) Offeror's capabilities, related experience, facilities, techniques, or unique combinations of these which are integral factors for achieving the proposal objectives.

(3) The qualifications, capabilities, and experience of the proposed Principal Investigator, team leader, or key personnel critical in achieving the proposal objectives.

(4) Overall standing among similar proposals and/or evaluation against the state-of-the-art.

d. Evaluation of the cost of a proposed effort includes the realism and reasonableness of the proposed cost and the relationship of the proposed cost and available funds.

14. Evaluation Techniques

Selection decisions will be made following peer and/or scientific review of the proposals. Several evaluation techniques are regularly used within NASA. In all cases proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house, others are evaluated by a combination of in-house and selected external reviewers, while yet others are subject to the full external peer review technique (with due regard for conflict-of- interest and protection of proposal information), such as by mail or through assembled panels. The final decisions are made by a NASA selecting official. A proposal which is scientifically and programmatically meritorious, but not selected for award during its initial review, may be included in subsequent reviews unless the proposer requests otherwise.

15. Selection for Award

a. When a proposal is not selected for award, and the proposer has indicated that the proposal is not to be held over for subsequent reviews, the proposer will be notified. NASA will explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a de-briefing.

b. When a proposal is selected for award, negotiation and award will be handled by the procurement office in the funding installation. The proposal is used as the basis for negotiation. The contracting officer may request certain business data and may forward a model contract and other information which will be of use during the contract negotiation.

16. Cancellation of NRA

NASA reserves the right to make no awards under this NRA and to cancel this NRA. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation. Cancellation may be followed by issuance and synopsis of a revised NRA, since amendment of an NRA is normally not permitted.

APPENDIX D
NRA-96-HEDS-03

NASA RESEARCH ANNOUNCEMENT (NRA) SCHEDULE

FUNDAMENTAL PHYSICS IN MICROGRAVITY:
RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

All proposals submitted in response to this Announcement are due on the date and at the address given below by the close of business (4:30 PM EDT). NASA reserves the right to consider proposals received after this deadline if such action is judged to be in the interest of the U.S. Government. A complete schedule of the review of the proposals is given below:

NRA Release Date: ....December 4, 1996

Letter of Intent Due: ....January 27, 1997

Proposal Due: ....March 25, 1997

Submit Proposal to:

Dr. Mark C. Lee
NASA c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-03)
300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

Final Selections: ....October, 1997

Funding commences: ....November, 1997
(dependent upon procurement process)

FORM A

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION OFFICE OF LIFE & MICROGRAVITY SCIENCES & APPLICATIONS MICROGRAVITY SCIENCES AND APPLICATIONS DIVISION **SOLICITED PROPOSAL APPLICATION** PLEASE FOLLOW INSTRUCTIONS CAREFULLY	LEAVE BLANK NUMBER REVIEW GROUP DATE RECEIVED

1. COMPLETE TITLE OF PROJECT

2. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR *(First, middle, and last name; degrees; position title)*

3. COMPLETE MAILING ADDRESS
Internal Mail Code or Location
Office or Organization Division
Agency/Center, Company, or Institution
Street or P.O. Box
City, State, Zip Code

4. TELEPHONE NUMBER *(area code, number, extension)* FAX NUMBER E-MAIL ADDRESS	5. CONGRESSIONAL DISTRICT 6. SOCIAL SECURITY #

7. IS THIS PROPOSAL ❑ NEW ❑ RENEWAL ❑ REVISED

8. HAS THIS PROPOSAL (OR SIMILAR REQUEST) BEEN SUBMITTED TO NASA OR ANY OTHER AGENCY?
❑ No ❑ Yes IF YES, SPECIFY AGENCY AND YEAR SUBMITTED:

9. CO-INVESTIGATORS *(First, middle, and last name; degrees)*	10. CO-INVESTIGATOR'S ORGANIZATION

11. DATES OF ENTIRE PROPOSED PROJECT PERIOD	12. COSTS REQUESTED FOR FIRST 12-MONTH BUDGET PERIOD		13. COSTS REQUESTED FOR ENTIRE PROPOSED PROJECT PERIOD	
	12a. Direct Costs	12b. Total Costs	13a. Direct Costs	13b. Total Costs
From: Through:	$	$	$	$

14. APPLICANT ORGANIZATION *(Organization Name)*

15. TYPE OF ORGANIZATION
❑ Non Profit ❑ For Profit *(General)* ❑ For Profit *(Small Business)* ❑ Public, Specify: ❑ Federal ❑ State ❑ Local

16. ORGANIZATION OFFICIAL TO BE NOTIFIED IF AN AWARD IS MADE *(Name, title, address and telephone number)*	17. OFFICIAL SIGNING FOR APPLICANTORGANIZATION *(Name, title, and telephone number)*

18. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR ASSURANCE: I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if a grant is awarded as a result of this application. Willful provision of false information is a criminal offense (U.S. Code, Title 18, Section 1001).

SIGNATURE OF PERSON NAMED IN 2
(In ink "Per" signature not acceptable.)

DATE

19. CERTIFICATION AND ACCEPTANCE: I certify that the statements herein are true and complete to the best of my knowledge, and accept the obligation to comply with NASA terms and conditions if a grant is awarded as the result of this application. A willfully false certification is a criminal offense (U.S. Code, Title 18, Section 1001).

SIGNATURE OF PERSON NAMED IN 17
(In ink "Per" signature not acceptable.)

DATE

FORM B

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR: ______________________

DETAILED BUDGET FOR 12-MONTH BUDGET PERIOD **DIRECT COSTS ONLY**		FROM	THROUGH		
Duplicate this form for each year of grant support requested		DOLLAR AMOUNT REQUESTS *(Omit cents)*			
PERSONNEL *(Applicant Organization Only)*		**EFFORT ON PROJECT**	**SALARY**	**FRINGE BENEFITS**	**TOTALS**
NAME	**ROLE IN PROJECT**				
	Principal Investigator				
	SUBTOTALS →				
CONSULTANT COSTS					
EQUIPMENT *(Itemize, use additional sheet if needed)*					
SUPPLIES *(Itemize by category, use additional sheet if needed)*					
TRAVEL	DOMESTIC				
	FOREIGN				
OTHER EXPENSES *(Itemize by category, use additional sheet if needed)*					

TOTAL DIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD *(Item 12a, Form A)*	**$**
INDIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD	**$**
TOTAL COSTS FOR FIRST 12-MONTH BUDGET PERIOD *(Item 12b, Form A)*	**$**

FORM C

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR: ____________________

BUDGET FOR ENTIRE PROJECT PERIOD DIRECT COSTS ONLY

BUDGET CATEGORY TOTALS		1st BUDGET PERIOD	ADDITIONAL YEARS OF SUPPORT REQUESTED		
			2nd	3rd	4th
PERSONNEL(Salary and Fringe Benefits) (Applicant organization only)					
CONSULTANT COSTS					
EQUIPMENT					
SUPPLIES					
TRAVEL	DOMESTIC				
	FOREIGN				
OTHER EXPENSES					
TOTAL DIRECT COSTS FOR EACH BUDGET PERIOD		**$**	**$**	**$**	**$**
TOTAL INDIRECT COSTS FOR EACH BUDGET PERIOD		**$**	**$**	**$**	**$**
TOTAL DIRECT + INDIRECT COSTS FOR EACH PERIOD		**$**	**$**	**$**	**$**

TOTAL DIRECT + INDIRECT COSTS FOR ENTIRE PROJECT	**$**

JUSTIFICATION FOR UNUSUAL EXPENSES (Detail Justification in Cost Section of Proposal)

FORM D

CERTIFICATION REGARDING DRUG-FREE WORKPLACE REQUIREMENTS

This certification is required by the regulations implementing the Drug-Free Workplace Act of 1988, 34 CFR Part 85, Subpart F. The regulations, published in the January 31, 1989 Federal Register, require certification by grantees, prior to award, that they will maintain a drug-free workplace. The certification set out below is a material representation of fact upon which reliance will be placed when the agency determines to award the grant. False certification or violation of the certification shall be grounds for suspension of payments, suspension or termination of grants, or government-wide suspension or debarment (see 34 CFR Part 85, Sections 85.615 and 85.620).

I. GRANTEES OTHER THAN INDIVIDUALS

A. The grantee certifies that it will provide a drug-free workplace by:

(a) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition;

(b) Establishing a drug-free awareness program to inform employees about --

(1) The dangers of drug abuse in the workplace;

(2) The grantees policy of maintaining a drug-free workplace;

(3) Any available drug counseling, rehabilitation, and employee assistance programs; and

(4) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace;

(c) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);

(d) Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will --

(1) Abide by the terms of the statement; and

(2) Notify the employer of any criminal drug statute conviction for a violation occurring in the workplace no later than five days after such conviction;

(e) Notifying the agency within ten days after receiving notice under subparagraph (d) (2) from an employee or otherwise receiving actual notice of such conviction;

(f) Taking one of the following actions, within 30 days of receiving notice under subparagraph (d) (2), with respect to any employee who is so convicted --

(1) Taking appropriate personnel action against such an employee, up to and including termination; or

(2) Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or Local health, Law enforcement, or other appropriate agency;

(g) Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraphs (a), (b), (c), (d), (e), and (f).

B. The grantee shall insert in the space provided below the site(s) for the performance or work done in connection with the specific grant: Place of Performance (Street address, city, county, state, zip code)

____

____

Check ____ if there are workplaces on file that are not identified here.

II. GRANTEES WHO ARE INDIVIDUALS

The grantee certifies that, as a condition of the grant, he or she will not engage in the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance in conducting any activity with the grant.

____

Organization Name | AO or NRA Number and Title

____

Printed Name and Title of Authorized Representative

____

Signature | Date

____

Printed Principal Investigator Name | Proposal Title

FORM E

CERTIFICATION REGARDING
DEBARMENT, SUSPENSION, AND OTHER RESPONSIBILITY MATTERS
PRIMARY COVERED TRANSACTIONS

This certification is required by the regulations implementing Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, Section 85.510, Participants' responsibilities. The regulations were published as Part VII of the May 28, 1988 Federal Register (pages 19160-19211). Copies of the regulations may be obtained by contacting the U.S. Department of Education, Grants and Contracts Service, 400 Maryland Avenue, S.W. (Room 3633 GSA Regional Office Building No. 3), Washington, D.C. 20202-4725, telephone (202) 732-2505.

A. The applicant certifies that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;
(b) Have not within a three-year period preceding this application been convicted or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or Local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;
(c) Are not presently indicted for or otherwise criminally or civilly charged by a government entity (Federal, State, or Local) with commission of any of the offenses enumerated in paragraph A.(b) of this certification; and
(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State, or Local) terminated for cause or default; and

B. Where the applicant is unable to certify to any of the statements in this certification, he or she shall attach an explanation to this application.

C. Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lowered Tier Covered Transactions (Subgrants or Subcontracts)

(a) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principles is presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any Federal department of agency.
(b) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

____
Organization Name AO or NRA Number and Title

____
Printed Name and Title of Authorized Representative

____
Signature Date

____
Printed Principal Investigator Name Proposal Title

FORM F

CERTIFICATION REGARDING LOBBYING

As required by S 1352 Title 31 of the U.S. Code for persons entering into a grant or cooperative agreement over $100,000, the applicant certifies that:

(a) No Federal appropriated funds have been paid or will be paid by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, in connection with making of any Federal grant, the entering into of any cooperative, and the extension, continuation, renewal, amendment, or modification of any Federal grant or cooperative agreement;

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting an officer or employee of any agency, Member of Congress, an or an employee of a Member of Congress in connection with this Federal grant or cooperative agreement, the undersigned shall complete Standard Form - LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(c) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subgrants, contracts under grants and cooperative agreements, and subcontracts), and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by S1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

____

Organization Name AO or NRA Number and name

____

Printed Name and Title of Authorized Representative

____

Signature Date

____

Printed Principal Investigator Name Proposal Title

NASA Research Announcement (NRA) Mailing List Update

This is the form to update information for the NASA Office of Life & Microgravity Sciences & Applications (OLMSA) NRA mailing list. Please fill out ***CONTACT INFORMATION*** *completely. Check only those that apply in* ***INSTITUTION TYPE*** *and* ***PROGRAM AREAS/DISCIPLINES****.* ***Fold the form, secure with tape (do not staple), and mail it back to the address on the reverse side. Proper postage must be applied.***

Mailing list updates may also be submitted electronically via E-Mail or World Wide Web to the following addresses:
E-Mail: list@hq.nasa.gov
World Wide Web: https://peer1.idi.usra.edu/

Check one:

- ☐ 1. Please **add** my name to the mailing list.
- ☐ 2. Please **remove** my name from the mailing list (please attach mailing label).
- ☐ 3. Please **change** my current listing (please attach mailing label).
- ☐ 4. Please leave my current listing **unchanged** (please attach mailing label).

Contact Information

If your address has changed or your mailing label is incorrect, please provide COMPLETE contact information.

Prefix: (Mr., Mrs., Ms., Dr., Prof., etc.)

Suffix: (M.D., Ph.D., Jr., III, etc.)

Name, First:

Last:

Position Title:

Mail Code, Loc:

Office, Dept, Div:

Univ/Agency/Ctr, Org.:

Street or PO Box:

City:

State:

Zip Code:

Country:

Telephone No:

Fax No:

Internet/E-Mail:

Institution Type

(check all that apply)

- ☐ 1. College or University
- ☐ 2. Minority College or University
- ☐ 3. Minority Business
- ☐ 4. NASA Center
- ☐ 5. Other Government Agency
- ☐ 6. Nonprofit Corporation
- ☐ 7. Small Business
- ☐ 8. Private Industry
- ☐ 9. Foreign Addressee

Program Areas/Disciplines

(check main area of interest)

- ☐ **1. Life Sciences**
  - ☐ A. Advanced Life Support
  - ☐ B. Advanced Technology Development
  - ☐ C. Data Analysis
  - ☐ D. Environmental Health
  - ☐ E. Space Biology
  - ☐ F. Space Human Factors
  - ☐ G. Space Physiology & Countermeasures
  - ☐ H. Space Radiation Health
- ☐ **2. Microgravity Sciences**
  - ☐ A. Biotechnology
  - ☐ B. Combustion Science
  - ☐ C. Fluid Physics
  - ☐ D. Fundamental Physics
  - ☐ E. Materials Science

☐ Please send me notifications of announcements via E-Mail only.

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NASA
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